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H...IMPEDANCE MEASUREMENT

A monitoring system for monitoring parameters of an apparatus, comprising a plurality of inputs for receiving a plurality of electrical analog signals representative of parameters of the apparatus, a multiplexing circuit for multiplexing the analog signals into sequential analog input signals, an auto-ranging circuit for individually scaling each of the sequential analog input signals to within a predetermined range suitable for digital processing thereof, a signal converter for converting the scaled sequential analog input signals into respective digital signals, and digital processing system for storing and/or manipulating the digital signals.

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## ELECTRICAL PARAMETER MONITORING SYSTEM

This invention relates to a system for monitoring electrical parameters. A particular application of the invention lies in the field of monitoring performance parameters of battery  
5 based or other power systems.

In many electrically operated systems, the integrity of the power supply is crucial to reliable operation, and this may include the integrity of a back-up power supply which is only actually utilised sporadically. An example is a telecommunications exchange installation, which  
10 ordinarily derives power from a mains supply connection, but is also provided with a battery based back-up power system to ensure the exchange can continue to operate in the event that the mains power should fail. The battery based power system is utilised only occasionally, however, it is nevertheless very important that it be continuously in a condition to enable it to power the telecommunications equipment at any time, since the loss of mains power cannot  
15 generally be predicted. Accordingly, various forms of testing apparatus have been developed in order to assess the condition of the batteries in the back-up power system, and one such form of testing apparatus is described in the specification of Australian Patent No. 688298. Typically, testing apparatuses of this type have been constructed so as to be portable, in order to be suitable to be carried by a service person from one installation to another for the  
20 purposes of periodic testing of the batteries at the installations.

Another approach to ensuring battery integrity involves continuous on-line monitoring. Commercially available battery monitoring systems typically involve broad-based surveillance of a relatively large number of batteries by centralised logging equipment. These systems are  
25 characteristically expensive and often require a secondary level or platform of support for the storage, processing and interpretation of collected data.

The present invention aims to provide a monitoring system which is flexible in its application and yet simple enough so that it can be implemented and operated at relatively low cost. It  
30 will be appreciated from the following description of the invention that the monitoring system

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is not merely applicable to battery based power systems, although the preferred embodiment described herein is in that context. Indeed, the monitoring system of the invention is not restricted to power systems or in fact even to monitoring electrical apparatus, as long as analog electrical signals can be generated for input to the monitoring system.

5

In accordance with the present invention, there is provided a monitoring system for monitoring parameters of an apparatus, comprising:

a plurality of inputs for receiving a plurality of electrical analog signals representative of parameters of said apparatus;

10 a multiplexing circuit for multiplexing said analog signals into sequential analog input signals;

an auto-ranging circuit for individually scaling each of said sequential analog input signals to within a predetermined range suitable for digital processing thereof;

a signal converter for converting the scaled sequential analog input signals into  
15 respective digital signals; and

digital processing means for storing and/or manipulating said digital signals.

The present invention further provides a method for monitoring parameters of an apparatus, comprising the steps of:

20 receiving a plurality of electrical analog signals representative of parameters of said apparatus;

multiplexing said analog signals into sequential analog input signals;

scaling each of said sequential analog input signals to within a predetermined range suitable for digital processing thereof;

25 converting the scaled sequential analog input signals into respective digital signals using signal converter means; and

storing and/or manipulating said digital signals using digital processing means. -

The present invention further provides a monitoring system, comprising:

30 an input means for receiving at least one electrical signal input;

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a data acquisition means for obtaining first data values representing the at least one signal input repeatedly sampled at a first time interval;

a first storage means for storing said first data values;

a first averaging means for generating second data values representing averaged values of said first data values over a second time interval; and

a second storage means for storing said second data values

The present invention further provides a monitor for monitoring a battery, comprising:

battery impedance means for generating sampled impedance measurements of the impedance of said at least one battery at predetermined sampling intervals; and

storage means for storing digital representations of said sampled impedance measurements in a plurality of memory means, each memory means being adapted to store representations of said sampled impedance measurements generated at respective different time intervals.

15

The present invention further provides a method of monitoring a plurality of batteries or cells, comprising:

repeatedly measuring an impedance of each of said plurality of batteries or cells over a predetermined time interval;

recording digital representations of the measured impedances; and

determining, using said digital representations, a measure of a time differential of the impedance of each of the plurality of batteries or cells.

Advantageously, embodiments of the invention enable on-line or "live", determination of impedances on all individual battery cells or other components for which impedance measurements might be taken.

The invention is described in greater detail hereinafter, by way of example only, with reference to a preferred embodiment thereof which is illustrated in the accompanying drawings, wherein:

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Figure 1 is a functional block diagram of a preferred embodiment of the invention, referred to herein as an intelligent monitoring system or IMS;

Figures 2 to 12 are circuit diagrams of interconnected components forming the IMS;

Figure 13 is a block diagram illustrating an input sampling arrangement according to  
5 one form of the invention;

Figure 14 is a flow diagram of the sampling procedure;

Figure 15 is a block diagram illustrating a storage system according to one form of the invention;

Figure 16 is a block diagram of the event recording functions of the IMS;

10 Figure 17 is a block diagram of primary functional software elements; and

Figure 18 is a block diagram illustrating the general input processing structure of the IMS.

A preferred embodiment of the present invention, referred to herein as an intelligent  
15 monitoring system (IMS), has been designed primarily for continuous monitoring of a power system, such as a battery based back-up power system for telecommunications exchanges and the like. Battery integrity is critical to the standby power function. Real-time continuous monitoring is considered to be part of the pathway to improved battery system reliability, particularly for installations using valve-regulated lead-acid (VRLA) battery technology.  
20 Integration of new techniques such as cell and battery impedance or conductance measurements has been advocated to both increase the efficacy of on-line monitoring systems, and to eliminate many of the problems associated with manual impedance measurement of on-line standby batteries.

25 The major influence in battery monitoring equipment functionality comes from considering the productivity of maintenance effort. The advantage of continuous monitoring to trap unattended events is obvious. The ability to track system performance during normal-line failures is useful and may avoid the inconvenience and risks associates from routine test discharging.



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However, the potential of monitors to guide corrective or proactive maintenance action is less evident. For instance, in a remote solar powered network, a low volts alarm may result in the dispatch of urgent maintenance action to recharge the batteries. The cause of the low battery capacity may not be evident, and this often results in costly, repeated call-outs. The reactive  
5 maintenance may be made more effective if the recent history of the power system performance parameters were at hand to help identify the cause of the under-charged condition.

The Intelligent Monitoring System, or IMS, is characterised by an "intelligent" balance  
10 between the data collection and storage activities (logging) and the system condition assessment tasks (monitoring). Each of the tasks can be allied with particular existing maintenance actions (or lack thereof). This concept lends itself well to power system monitors, not just battery monitors. Further, the IMS is independent of either the centralised or local status of the battery data collection activities associated with commercial battery  
15 monitoring systems.

The preferred form of the IMS results in very decoupled software and hardware. That is, the tasking software is functionality objective, and could easily execute on other hardware. This is an important outcome because many commercial battery monitoring systems lose some  
20 functionality because of inflexible coupling of operating software with the physical hardware. In the attempt to achieve a low cost, "universal" battery and power monitoring system, the parameters required to be monitored should be considered. The dilemma of what, how and why to measure in a battery monitoring system typically skews hardware design and selection. However, some gains can be made by firstly recognising that, for standby services, there is  
25 no genuine battery fuel gauge, and secondly, most of the conventional physical parameter measurements are historical in origin. From a pragmatic point of view, recently reported techniques indicate that better methods to determine critical battery "state-of-health" criteria can reasonably be expected in the future. It therefore follows that a newly developed battery monitoring system should preferably exhibit flexibility to accommodate changes to both the  
30 collection and utilisation of the parameter set.

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The IMS is based on a generalised voltage input data acquisition design and does not limit the type of input parameter. There are, of course, limits placed on both the dynamic range of the voltage presented to the analog input multiplexer hardware, and the physical number of analog input channels available, but these limits need not affect the actual software tasking  
5 functionality. In a telecommunications network, the battery banks in the network exchanges might typically be based on a traditional  $24 \times 2V$  cell configuration, and this may therefore form a driving criterion for dynamic range and number of input channel limitations. Situations requiring more input channels, say for UPS applications or for multiple parallel battery banks, can be addressed by using more than one IMS. The major cost of a battery monitoring system  
10 is generally in the analog input acquisition circuitry, not in the support digital electronics. It is thus more cost effective to utilise multiple devices operating the same software than it is to have multiple input structures (to accommodate different battery installations) with associated variations in software.

15 In the IMS described herein, it will be recognised as significant by those skilled in the art that, for the purposes of the monitoring operations of the IMS, it is unimportant what voltage is presented at any one of the analog inputs, as long as it is smaller in magnitude than the maximum voltage rating of the input circuitry, since the input voltage range is independent of the voltage provided to the power supply of the IMS.

20

An attractive feature of the IMS is in the local event recording function performed primarily through the controlling software. Figure 16 illustrates the different types of event recording classes implemented in the preferred IMS. In practical terms, the Trend Tracker and Battery History classes relate to continuous logging activities, while the Discharge Logger and  
25 Exception Register relate more to random and unpredictable real-time events.

Each event type can be associated either directly or indirectly with one or more real inputs. As an example, Figure 17 illustrates in a functional sense how three different windows of trend tracking can be achieved within the IMS. Short-term, mid-term and long-term data  
30 describing system parameters and any derived information are available at any time. Table

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1, below, lists typical time dimensions for these trend windows. For example, 8 hours of the most recent time sequential processed data, time-resolved to 5 minutes, is locally available for any and all of the defined inputs associated with the short-term trend. Similarly, the mid-term trend contains the most recent 8 day history, resolved to 1 hour. The long-term trend gives the most recent 30 day trend. Ultimately, the trend data is selectively filtered off into the Battery History register. The Battery History is the automation of the existing prescribed manual battery measurement routines, and as such can be described as the "electronic battery book". The Battery History data is protected, thus creating a local, electronic, permanent record of performance over the service life of the battery.

10

Trend Tracker	t sampling rate	T trend window	n no. of samples
short-term	5 min	8 hr	96
mid-term	1 hr	8 day	196
long-term	24 hr	30 day	30
15 Battery-History	30 day	unlimited	unlimited

Table 1: Typical trend window dimensions

The trend trackers in the preferred IMS comprise circular memory designs, and thus only the most recent trend data is locally available. This recognises that in relation to Table 1, storage of 5 minute samples for the life of the battery is both unreasonable and unnecessary. From an operational point of view, the more recent history information is most relevant. Connection of the IMS to a remote device provides a means to build an extended set of highly time-resolved data by retrieving data at a more frequent rate.

25

The surprising outcome of this approach is the relatively low rate of local memory consumption. The IMS can be implemented with only 64kB of RAM with less than 20% consumption per year of operation for the typical 24 cell battery installation using 30 day history records. Such low memory requirements reduce costs, limits the physical size and

enables useful local functionality without the need for centralised data collection.

The general specifications and features of a particular implementation of the IMS are given in Table 2, and some typical input parameter assignments are listed in Table 3. The preferred device has a 32 channel voltage input structure arising from modelling the 24×2V cell structure of the standard 48V battery bank installation. Other types of battery banks, except for UPS installations, can be modelled as a subset of the 24 cell situation. Generally, UPS installations require more numerous parameters to be monitored, but this can usually be accommodated by some integer multiple of 24 or 32. The input channels have a high common-mode voltage tolerance and an auto-ranging function ensures that there is no functional difference between 2V cells and 6V or 12V monoblocks.

	Category	Description
15	Analog Input range Scaling A/D Conversion	32 differential channels ±160V (2000V isolation) Auto-ranging 13 bit 100 $\mu$ sec, SAR ADC
20	Digital RAM ROM User interface Remote access	68HC11 series 8 bit CPU 32K-128K non-volatile 128K UVEPROM (secure) 2-line LCD display and keypad Isolated RS-232 (9 pin)
25	Powering Operating range Power consumption	Self-powered by monitored battery ±8V-±100V, fully isolated Approx. 1-2 Watt average
	Physical Dimensions Input loom	104 (W) × 50 (H) × 270 (L) mm Universal 68 way mini-Centronics

30

Table 2: Some IMS hardware specifications

The IMS is self-powered from the battery installation under measurement and has very low power consumption. Collected data is memory protected. A standardised, "universal" input loom is utilised for all battery configurations. Intercell conduction integrity is directly

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measured by a two wire per cell or monoblock connection scheme. The IMS can utilise a single frequency or multiple frequency impedance measurement as a core set of the battery and power system parameter set. Battery health information can be made on the basis of time trends in impedance measured at a single (same) frequency, or in changes in the ratio of  
5 impedance measurement at one frequency compared to another. Configuration options are software implemented, so that there are no hardware switches or settings, thus avoiding the need for field adjustment and the possibility of incorrect configuration.

The controlling "Software Construct" of the IMS is based upon an "owner-user" model in  
10 which the "owner" and "user" are responsible for different aspects of the IMS configuration and operation functions. The software functions as a rule-based expert system which is configurable by the "owner" to suit the application for which the particular IMS is intended. For example, because the IMS is constructed as a "universal" monitoring device, the plural physical inputs are undefined at the time of manufacture, and must be assigned some context  
15 before installation.

The software construct allows the IMS to identify classes of events, which relate to the physical state (status) of the system being monitored by the IMS (for example, in battery and power system monitoring, whether the system is in charge, discharge, or standby (float)  
20 condition). The occurrence of an event (transition between one state to another) is recorded by the IMS for the life of the installation. This is important in analysis of conditions which may result in an exception, as well as providing statistics about the operation of the systems which would otherwise not be recorded with current practises or with traditional types of battery monitors. Information gathered during an event is used by the expert system rule book  
25 to build a picture of the health of the system. For instance, if during a charge event, the time for charge of one or more cells is unreasonably long, then those cells are indicated to be of poor health, and require attention.

The Construct allows conceptualisation of IMS into generic functional elements, which can  
30 go through the process of coding. The IMS Construct allows retaining most of the generic

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characteristics of a particular task or process at the higher levels of the software. IMS functionality specific to power and battery monitoring scenarios rises from User-defined adaptation of the generic Construct. In this respect, the IMS software is not hardware specific, and hardware devices different from the hardware described herein could be used. Specific  
5 coding to interface the IMS hardware to the IMS software occurs at low levels and does not involve higher level processes.

There are seven Primary Elements (PE) of the IMS Software Construct, and these are illustrated in block diagram form in Figure 19. The purpose of each of the Primary Elements  
10 is described briefly below.

Primary Element	Description
Configuration and Security (CS)	This procedure allows the Owner to define the operational functions of the IMS. Birth (initialisation) occurs through the configuration modules via the serial port only. Birth creates the Primary Task list for the Sequencer. The Owner-User Security monitor is located in this element. Wake-up (after power down instances) or re-configuration by the Owner also is vectored through this element. Limited self-testing is performed during configuration before passing control to the Primary Sequencer.
5 Primary sequencer (PS)	This is the high level process engine which polls through the task list. The task list originates from the Configuration Element. This process assembles and passes time-based requests for activity by one or more of the other Primary Elements.
User Interface (UI)	This element handles all User-interface interaction and data transfer. This includes all keypad and LCD display processes and all digital communications via the serial port.
Analysis (expert-system) Engine (AE)	This process is a high level background task which performs all data checking, exception condition testing and trend estimates, according to Owner-defined options at configuration time. The event recorder functions are also embedded in this process.
10 Database Engine (DBE)	This is a mid-level process which takes the current real-time data and performs the second level data averaging and statistical manipulation (as defined by the Owner at configuration time). This process also builds the binning scheme used in the trend recording.
User-defined Reality Translator (RT)	This process takes and manipulates raw sampled data from actual input channels and derives a virtual-inputs matrix. A virtual input is a real physical input or the mathematical or temporal combination of one or more physical inputs. The virtual inputs are then associated with parameters, units and scaling defined by the User, prior to feeding the Database.
15 Analog Input Engine (AIE)	This is the core, or inner-most process. This process assembles the time-dependent input channel sampling matrix and acquires real-time data accordingly. Auto-ranging and first level data averaging is done in this process.

Figure 18 is a block diagram which illustrates the general input processing structure of the IMS. The physical inputs 302 are, in use, each coupled to a node in the power system to be  
 20 monitored, or to a transducer or measuring apparatus such as a temperature sensor or the like

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for measuring a related quantity. Each of the physical inputs is identical and so may be arbitrarily coupled to the nodes to be monitored, and it is the connectivity matrix 340 which stores a correspondence between the physical inputs 302 and the monitored system nodes. The software controls a multiplexer matrix (described in greater detail hereinbelow) based on the connectivity matrix 340 in order to provide appropriate connections to measure desired electrical potential differences between various ones of the monitored system nodes. Thus, the connectivity matrix 340 contains the information which links otherwise arbitrary physical inputs with particular electrical quantities which are desired to be monitored by the IMS.

10 The combinations of physical inputs 302 which are dictated by the connectivity matrix 340 define a set of measured parameters 350 which represent the potential differences between various nodes in the monitored system, or other voltage based measurements representing quantities such as impedance and temperature. An association data matrix 360 is constructed to allow the measured parameters 350 to be assigned a correspondence to a set of virtual parameters 370. Each of the virtual parameters 370 incorporates any scaling factors which may be required in order to make the monitored measurements meaningful, and each virtual parameter is associated with a unit of measurement corresponding to the measured quantity (e.g. volts, milliamps, ohms, etc.). In the simplest case a virtual parameter may correspond directly to a pair of physical inputs between which a potential difference is measured.

20 However the virtual parameters are not limited to a direct correspondence with the physical inputs 302 or measured parameters 350, and the association matrix 360 may define virtual parameters which are combinations of other defined virtual parameters. For example, a virtual parameter representing an electrical power measurement can be defined in the association matrix as a multiplication of a first virtual parameter representing a voltage measurement and

25 a second virtual parameter representing a corresponding electrical current measurement.

Once the virtual parameters have been established, the monitored values are sampled and stored in a data storage memory 380 at selected time intervals. The sampling and storage rates need not be the same. The structure of the data storage memory and the storage procedure

30 employed is described in greater detail hereinbelow.



Input Associations
<ul style="list-style-type: none"> <li>• Battery bank(s) voltage and impedance</li> <li>• Cell or Monoblock voltages and impedances</li> <li>• Interconnection voltages and impedances</li> <li>• String float and load current</li> <li>• System temperatures</li> <li>• Amp-hours passed</li> <li>• Array current input (solar)</li> </ul>

**Table 3:** List of typical system parameters measured and utilised in the IMS

A functional block diagram of a preferred embodiment of the IMS 2 is shown in Figure 1. The IMS 2 comprises generally a digital processing circuit 100, a power supply circuit 200, an analog processing circuit 300, and an impedance measurement circuit 400. The IMS 2 illustrated is adapted for monitoring a battery stand-by power system, such as in a telecommunications exchange or the like, and the purpose of the impedance measurement circuit 400 is for impedance measurement of lead-acid batteries. Accordingly, in a monitoring system which does not utilise lead acid batteries the impedance measurement circuit 400 may not be required, although other impedance measurements may be advantageous in other applications of the IMS.

A plurality of analog voltage inputs 303 from the monitored apparatus are provided to the IMS 2 by way of an analog I/O connection 302. The analog voltage inputs 303 pass from the analog I/O connection 302 to an input multiplexer matrix 40 of the analog processing circuit 300. Selected signals from the input multiplexer matrix 40 are passed to an input gain and attenuation stage 44 which provides an auto ranging function. From the input gain and attenuation stage the signals are passed to an analog to digital conversion stage 64 whereat the signals are converted to digital representations for processing by the digital processing circuit 100.

The digital processing circuit 100 comprises a general purpose central processing unit having, for example, a microprocessor, memory in the form of RAM and/or ROM, and input/output

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interface devices such as a keypad and LCD display. The digital processing circuit 100 also includes digital interface ports enabling digital signals to be received from the analog processing circuit 300 and control signals to be issued to the impedance measurement circuit 400 and analog processing circuit 300. A serial port (not shown) is also provided to enable  
5 digital communications with circuitry external to the IMS 2.

The power supply 200 receives its primary power from an external system via line 202 and provides the appropriate voltage level power for the analog processing circuit 300, the digital processing circuit 100 and the impedance measurement circuit 400, and preferably derives this  
10 power from the monitored system. The power supply 200 is in the form of a wide range switch mode power supply, which enables it to be supplied with input voltages in a wide range (eg 8 volts to 100 volts) whilst still providing a regulated output suitable for the processing circuits of the IMS 2.

15 The impedance measurement circuit 400 is provided, as mentioned, for measuring the impedance of batteries, for example, in the monitored power system. The impedance measurement circuit 400 operates by injecting an alternating current into the battery to be measured via an I/O connection 402, along with synchronous detection of the voltage thereat. The impedance measurement circuit 400 may comprise a system, for example, of the type  
20 described in the specification of Australian Patent No. 688298, the disclosure of which is incorporated herein by reference. Other impedance measurement techniques may alternatively be employed, of course.

Figures 2 to 12 constitute a component level circuit diagram of the IMS 2. Briefly, Figures  
25 2 to 5 and 12 comprise circuit diagrams representing the digital processing circuit 100, Figures 6 and 7 illustrate the analog processing circuit 300, Figure 8 illustrates the switch mode power supply 200, and Figures 9, 10 and 11 illustrate the impedance measurement circuit 400.

30 Referring firstly to Figures 2 to 5 and 12, the illustrated form of the digital processing circuit

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100 comprises a single chip micro controller 10, which is coupled to a programmable peripheral device 12. The micro controller 10 and programmable peripheral device 12 are coupled together in conventional manner by way of address and data buses. The programmable peripheral device 12 provides additional decoded interface lines on ports A (shown as PA0 to PA7) and B (shown as PB0 to PB7) for controlling the analog processing circuit 300 and impedance measurement circuit 400, as well as other portions of the digital processing circuit itself. A memory circuit 14 is coupled to the address and data buses and control lines from the programmable peripheral device 12, and in this instance comprises a one Mbit RAM (128 kbytes) with SmartWatch DS1216D (Figure 3). An LCD display I/O port 16 is also connected to the data bus and control bus for interface to an LCD display device, and a keypad encoder 18 interconnects the databus with a keypad 20, of conventional form.

Referring to Figure 5, the lower address bus 11 is provided as input to a gate array logic circuit (GAL) 30 which decodes addresses into a plurality of control lines for controlling the analog processing circuit 300. The GAL 30 also provides a clocking input to a gate array logic circuit 32 which receives the databus 13 as input for decoding to control lines RD0 to RD7. An octal latch 34 is also clocked by an output of the GAL 30, and latches the databus 13 to respective inputs of driving transistors 36 which drive control lines RS0 to RS7. The control lines RD0 to RD7 and RS0 to RS7 constitute the control lines for the input multiplexor matrix 40 described hereinbelow.

Interface circuitry 22 and communications circuitry 120 (Figures 4 and 12, respectively) provide the capability for additional communication with the digital processing circuit 100. Interface circuitry 22 enables access to CPU ports A and D (shown as PD0 to PD5), and interfaces serial transmit and receive lines (TXD, RXD) between the micro controller 10 and communications circuit 120. The transmit and receive lines are coupled through opto-couplers 126 to an RS232 line generator 122, which provides an RS232 port for serial communication with the digital processing circuit 100.

The control lines RD0 to RD7 and RS0 to RS7 are coupled from the logic and latching

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circuitry of the digital processing circuit 100 (Figure 5) to a multiplexor matrix array 40 (Figure 6), which comprises a plurality of photo-MOS relays 42. 64 voltage inputs from the monitored apparatus are provided to the IMS by way of the analog I/O connection 302, and the analog voltage inputs are coupled to respective photo-MOS relays 42. The photo-MOS relays are arranged in a matrix configuration and controlled by the aforementioned control lines RD0 to RD7 and RS0 to RS7, in order to multiplex the 64 analog voltage input lines onto 2 analog voltage output lines (A and B). The analog output lines A, B from the MUX array 40 are coupled to additional multiplexing circuitry 45, in the form of photo-MOS relays 46, 48 and 50, shown in Figure 7. The multiplexing circuitry 45 is controlled by control line V/Z from the digital processing circuit 100, and allows inputs B<sub>0</sub>, B<sub>1</sub>, A<sub>0</sub> and A<sub>1</sub> from the impedance measurement circuit to be multiplexed with the voltage lines A, B. The outputs A', B' from the MUX circuit 45 are applied across series resistors R12, R13, R14, R15, R16, R17, R18 and R19 which constitute a voltage divider 52. Outputs of the voltage divider 52 are coupled to a further multiplexing circuit 54 comprising photo-MOS relays 56, 58 which are controlled by control lines ATT0 to ATT3 provided from the GAL circuit 30 (Figure 5). The voltage divider 52 and MUX circuit 54 provide the auto ranging function of the analog processing circuit 300. Appropriate application of the control lines ATT0 to ATT3 enables an output of the voltage divider 52 (Figure 7) to be selected which provides an output on lines HI, LO, which is in a range (eg -5 volts to +5 volts) which is suitable for digital processing, as long as the input analog voltage does not exceed the maximum input voltage limit. The appropriately attenuated analog signal on lines HI, LO are provided as input to a precision instrumentation amplifier circuit 60. The amplifier circuit 60 allows amplification of the analog signal in the event that this is required, and the amplification is controlled by control line GAIN from GAL circuit 30, switched through photo-MOS relay 62. The output of amplifier 60 is coupled to the analog input of an analog to digital converter circuit 64 (having 12 bits of magnitude resolution plus one bit of sign data), for conversion of the analog voltage signal level to a digital representation which is output on the databus 13. A precision 12 volt reference circuit 66 provides a reference voltage input to the A-D convertor 64.

The wide range switch mode power supply 200 is illustrated in component form in Figure 8,

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and details of its operation are omitted here so as to prevent obscuring the clarity of description of the invention as a whole. Briefly, input power is provided at  $V_x$  and  $V_y$ , and is rectified and regulated through voltage regulators 76 to provide supply voltages of  $\pm 5$  volts at  $V_d$  and  $V_s$  and  $\pm 12$  volts at  $V_{dd}$  and  $V_{ss}$ . The power supply 200 is able to operate on input  
5 voltages between about 8 volts and 100 volts, and this wide range is facilitated by the use of a pulse width modulation (PWM) controller 72 and voltage reference diode 74 which is coupled thereto by way of an opto-coupler 75. The detailed operation of the switch mode power supply 200 will be readily ascertainable by those skilled in the art from the circuit level diagram provided in Figure 8.

10

Figures 9, 10 and 11 illustrate the circuitry for the impedance measurement circuit 400. A single frequency current injection circuit 80 is illustrated in Figure 9, and the operation will be readily apparent to those skilled in the art from a detailed examination of the circuit in conjunction with the theory of operation of such a battery impedance measurement circuit as  
15 described in the aforementioned Australian patent specification. In essence, a single frequency signal is generated by a frequency generator 82, is amplified using power darlington transistors 84, and output on lines  $-I$ ,  $+I$ . The current injection signals  $-I$ ,  $+I$  are provided to an array of reed relays 116 (Figure 11) which form part of a switching circuit 110 controlled by a programmable gate array logic circuit 114. The GAL 114 is driven from the  
20 databus 13, and enables the current injection signals to be selectively output through output connector 115 to battery terminals of the monitored apparatus. The impedance receiving and demodulating circuitry for impedance measurement circuit 400 is shown in Figure 10, which is provided with an AC input voltage signal on lines INA and INB. The input signals are amplified through an instrumentation amplifier 92, and demodulated using a synchronous  
25 demodulator circuit 94 and output through a low pass filter 96.

Impedance measurements which are taken in this way can vary depending upon the actual length of the electrical cables which are used to couple the IMS physical inputs to the nodes of the monitored system. In order to alleviate this difficulty the IMS may be arranged with  
30 a dedicated input channel to which is coupled an accurately known electrical resistance. By

taking an impedance measurement across the known resistance, including whatever connecting leads are used, and comparing the measured value with the known resistance value the IMS controlling software is then able to determine a calibration constant for impedance measurements, which may then be factored in to the monitored impedance values before storage thereof. For example, the calibration factor may be included in the association matrix 360 during calculation of the virtual parameters 370 (Figure 18). In practice it has been found suitable to in fact provide two known impedances, one which is situated on board as part of the IMS circuitry and the other which is coupled to the input circuitry of the IMS by way of leads corresponding to the longest used for coupling other monitored nodes to the IMS. By taking one measurement from the on-board impedance and another from the known impedance and leads, the IMS controlling software is able to determine a linear correction factor for impedance measurements which then take into account the resistance added by the connecting leads, thus enabling more accurate impedance measurements to be taken.

Figure 13 shows a block diagram of the analog processing circuit 300, for the purposes of simplified explanation. Sixty-four analog voltage inputs are provided to the input multiplexor matrix 40 through analog I/O connection 302. The MUX 40 is in the form of a matrix of photo-MOS relays 42 (Figure 6), which are utilised as the switching elements because of their ability to handle up to about 2000 volts at the controlled input without breakdown. Furthermore, the photo-MOS relays do not use as much power as, for example, mechanical relays, which is important where the IMS is to be powered from the monitored apparatus such as a battery stand-by power system. Sixteen control lines RS0 to RS7 and RD0 to RD7 are also provided as input to the MUX array 40. One of each of RS0-7 and RD0-7 are active at any given time, so as to select 2 of the 64 analog inputs to be passed through the MUX 40 to outputs A, B. The analog voltage provided at the selected output lines A, B is applied across a voltage divider circuit 52, which comprises a plurality of series connected resistors (see Figure 7). Taps on the voltage divider 52 provide a plurality of voltage signal outputs having respective voltage magnitudes of some fraction of the potential difference between output lines A and B. The respective fractional voltage outputs are provided to multiplexing selection circuit 54, at which one of the fractional voltage outputs is selected according to control lines

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ATT0 to ATT3. The fractional voltage output is selected according to which one has a voltage level most appropriate for digital signal processing. For example, if the analog voltage input is quite large (eg of the order of 100 volts) then the fractional voltage output which would be selected would be that having the greatest attenuation so that the fractional voltage output is of the order of 5 volts. On the other hand, if the analog voltage input is quite small (of the order of 4 volts), then the fractional voltage output selected may be that output having no attenuation.

As mentioned, the output from the voltage divider 52 having the appropriate amount of attenuation is selected by use of the control lines ATT0 to ATT3 through the multiplexor selector 54. The control lines ATT0 to ATT3 are controlled from the digital processing circuit 100, and may be controlled according to a predetermined selection criteria corresponding to the active control lines to the input multiplexor matrix 40. For example, the digital processing circuit may be pre-programmed to activate a particular one of the control lines ATT0 to ATT3 for each selection of the MUX circuit 40 on the basis of a priori knowledge of the expected analog voltage signal amplitude for the MUX 40 selection. Alternatively, a feedback arrangement from the output of the multiplexor selector 54 may be provided to the digital processing circuit 100, including at least one voltage comparator, comparing the output of the MUX 54 with a reference voltage to determine which selection of the MUX 54 provides an output in a suitable range for processing by the analog to digital convertor 64. In practice it has been found suitable to begin each measurement with the voltage divider on the highest possible attenuation, and cascade successively through the attenuation levels until the attenuated input signal is in the appropriate range, which may be judged by way of the overflow register of the analog to digital converter.

25

The output from multiplexor selector 54 is passed to an amplifier section 60, which is provided to boost the signal amplitude of analog input signal levels which are too low for good conversion to digital quantities. In the case of such an input signal with low amplitude, whether it be known a priori or detected using a level comparator as discussed above, the signal selected from the voltage divider 52 by the MUX 54 is without attenuation, and a

30

- 20 -

GAIN signal is applied to the amplifier 60 in order to boost the output amplitude thereof. The GAIN signal is similarly provided from the digital processing circuit 100. In the case of a signal which has been attenuated by the voltage divider 52 the gain control may, or may not be applied, depending upon the actual signal amplitude required.

5

The output of amplifier 60 is coupled to the input of an analog to digital conversion circuit 64 which, in the case of the preferred embodiment, converts the analog input to a 12 bit digital representation thereof. The digitally converted signal is output onto the databus 13 for processing and/or storage by the digital processing circuit 100.

10

The flow chart 150 shown in Figure 14 illustrates the basic procedure carried out by the IMS apparatus. The first step (step 152) is the selection of an analog input from the plurality of analog voltage inputs at the analog I/O connection 302. This is performed by the input multiplexor matrix circuit 40, and may entail selecting a pair of inputs from 32 pairs, for  
15 example. The analog voltage inputs are provided from sources external to the IMS apparatus, and may include direct voltage readings from various parts of the power system, for example, together with other forms of voltage inputs from sensors such as temperature sensors, current sensors and the like. Analog voltage signals from the impedance measurement circuit 400 are considered in this category also, although the impedance measurement circuit 400 itself forms  
20 part of the IMS in the preferred embodiment. Once a particular analog input has been selected, scaling of the analog signal must be adjusted utilising an auto ranging circuit (step 154). This is required to enable the IMS to receive analog inputs within a broad range of signal levels which facilitates flexibility of the IMS apparatus. For example, in the preferred embodiment, analog signal levels within the range of -160 to +160 volts can be handled.  
25 Because of the wide range of possible analog input voltage levels, it is necessary to adjust the scaling according to the particular selected analog input before conversion to digital representation, since an analog to digital convertor circuit can typically only handle voltages within a much smaller range. For example, an A/D convertor may be adapted to convert analog signals which are only in the range of -5 to +5 volts, and input voltage levels outside  
30 that range may damage the circuit, or at least saturate the output. Although it would be



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possible to simply attenuate all of the analog input signals the same amount so that the maximum input voltage level corresponds to the maximum voltage level presented to the A/D convertor, this would necessarily reduce the accuracy of measurement samples for input signals having levels significantly less than the maximum. It may also be necessary to provide  
5 for amplification of some analog input signal levels for the same reason, and for this purpose the aforementioned amplifier circuit 60 is provided.

Once the scaling of the analog input signal level has been adjusted to an appropriate range for the A/D convertor (64), the signal is repeatedly sampled over a time slice period of, for  
10 example, several milliseconds, at step 156. The actual number of samples taken may depend upon the time slice period which is selected, which may in turn depend upon the actual number of analog inputs to the multiplexing circuit 40 and the frequency with which it is desired to determine the level of each input. For example, if there are 32 analog inputs and it is desired to determine the signal level of each input once every second, then it would be  
15 possible to set each sampling time slice period to approximately 30 milliseconds. The number of samples of a particular input which can be taken during the time slice period will of course depend upon the sampling speed of the A/D convertor. The repeated sampling of an analog input over a time slice period enables transient fluctuations which are shorter in duration than the time slice period to be averaged out. In order to deal with these fluctuations, the plurality  
20 of samples taken during the time slice period are averaged over the time slice in step 158 and stored in a sampled data pool in the digital processing circuit 100. The next analog input is then selected using the multiplexing circuit 40 (step 160), before the procedure returns to step 154 to adjust the scaling for the new analog input voltage level. Transient fluctuations could alternatively be accommodated by using a sample-hold technique in the analog-to-digital  
25 conversion process.

In the above mentioned example where the level of each analog input is determined once every second, it is immediately apparent that, in the context of a monitoring system, the amount of memory which would be required in order to store every averaged sample for every  
30 input over any substantial length of time would be quite large. For example, in that scenario

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approximately 20 megabytes of memory would be required in order to store one weeks worth of sampled data. Clearly this is prohibitive for a monitoring system which may be required to operate unattended over lengths of time of the order of years. Accordingly, the IMS apparatus of the preferred embodiment implements a "bin storage" system for storing sampled  
5 analog input data over a long period of time, and at the same time providing a useful representation of that data over various time frames. This storage procedure is represented by step 162 in flow chart 150, and is illustrated in greater detail in flow chart 170 shown in Figure 15.

10 The flow chart 170 shown in Figure 15 illustrates the "bin storage" procedure for storage of sampled data in the digital processing circuit 100 of the IMS 2. The analog voltage inputs are provided at stage 172, and time based data acquisition of the analog input voltage levels are obtained at stage 174. The time based data acquisition stage 174 in this case includes both the multiplexing by use of MUX 40 under control of the digital processing circuit, and the  
15 repeated sampling over a time slice period discussed hereinabove in connection with Figure 14. The plurality of instantaneous values 175 for each input channel which are obtained from stage 174 are averaged for each channel at stage 176 in order to reduce the effect of fluctuations and the like which are shorter in duration than the time slice period. The averaged point values 177 for each channel, generated at stage 176, are passed to the sampled data pool  
20 178 and stored for a predetermined time in, for example, a circular memory or FIFO buffer. From the sampled data pool 178 the averaged sample data is then processed into the bin storage memory at stages 180 to 194, as described hereinbelow.

The bin storage process involves a sequence of averaging engines and loop memories. Each  
25 loop memory stores data over a different length of time, and during that length of time the data therein is averaged and stored in the next loop memory having a longer term. In the example shown in Figure 15, the bin storage includes a short term loop memory 182 which holds 8 hours worth of data, with each data element representing a 5 minute interval of the input signals monitored by the IMS. Thus, advantageously the sampled data pool 178 is  
30 arranged to store at least 5 minutes worth of averaged sample data which, as mentioned, may

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be taken at 1 second intervals. For each channel, the short term averaging engine 180 takes the most recent 5 minutes worth of 1 second interval averaged sample data (eg 300 averaged samples) and applies an averaging algorithm to reduce the stored averaged sample data for that channel to a single short term data element. The short term averaging engine 180 and the short term loop memory 182 form part of the short term trend 181, which is used for analysing changes in system parameters over the short term.

While an averaging engine is utilised for stage 180 (and for stages 184, 188 and 192, discussed below), the algorithm carried out thereby may not in fact comprise an averaging process in the traditional sense, and several different techniques may be advantageously employed. For example, instead of merely summing the data samples and dividing by the number of samples, as in a traditional averaging process, the averaging engine 180 (184, 188, 192) may alternatively apply a threshold, for example, to determine how often the sampled data value rises above or falls below a given threshold. Other common processing techniques may alternatively be applied, and will be apparent to those skilled in the art.

In any event, the processing applied by the short term averaging engine 180 reduces the 5 minutes worth of sampled data in the sampled data pool 178, for each channel, to a single short term data element which is stored in the short term loop memory 182. Over an eight hour period this data element passes from the input to the output of the short term loop memory 182 which, when full, comprises 96 data elements for each channel, each representing a 5 minute interval.

Once each hour the most recent 12 data elements in the short term loop memory 182 are examined by the mid term averaging engine 184. These 12 data points are averaged using the same process as the short term averaging engine 180, although a different process may alternatively be applicable. The result from the mid term averaging engine 184, for each channel, is a mid term data element each hour, representing one hour of sampled data for each channel respectively. The mid term data element is provided, as to the input of a mid term loop memory 186, which has a capacity of 192 one hour data elements for each channel,

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representing an 8 day history for each channel. The mid term trend 185 is similar to the short term trend 181 but except that the analysis is carried out over longer sampling intervals.

Similarly, a long term averaging engine 188 samples the most recent 24 mid term data elements in the mid term loop memory 186 once per day. The output of the long term averaging engine 188 is provided to the input of a long term loop memory 190 and is used in the long term trend 189. The long term loop memory ideally has a capacity of 90 one day interval long term data elements for each channel. Finally, once every 30 days the most recent 30 long term data elements are averaged by a history building engine 192, and stored in a history register memory 194, which retains one month averaged data for each channel for the life of the monitoring installation of the IMS.

The bin storage process is particularly useful in that it provides an indication of a trend in sampled data for each channel over a plurality of time frames. Furthermore, depending upon the algorithm utilised by each averaging engine 180, 184, 188, 192, relevant events in the monitored parameters represented by the sampled channels will be preserved, and trends in the behaviour of the parameters can be observed over the time frames represented by the various loop memories of the bin storage system. The history register preserves the behaviour of the monitored parameters over the lifetime of the IMS installation, the long term loop memory stores the most recent 90 days of behavioural data at one day resolution, the mid term loop memory stores the most recent 8 days of parameter data of 1 hour resolution, the short term loop memory continually holds the most recent 8 hours of parameter data of 5 minute intervals, and the sampled data pool at any time holds 5 minutes worth of parameter data for each input channel at the finest resolution of 1 second intervals.

25

The form of the data provided by the bin storage process is advantageous not only for analysis of past performance of the monitored apparatus, but can also be useful for predicting future performance. As mentioned, the bin storage provides, in the described example, data which can indicate trends in the monitored apparatus parameters over a plurality of time frames, and these trends can be utilised in some instances to predict future performance of the monitored

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parameters. For example, in a typical application of the IMS in which the impedance measurement circuit 400 is employed to measure the impedance of battery cells in a standby power system, these impedance measurements are presented to the analog processing circuit 300 amongst the other analog input signals. Because the impedance measurements are made  
5 very frequently by the continuously monitoring IMS, the resulting impedance ( $Z$ ) measurement data is of very high resolution and wide dynamic range. Taken over a time period such as that stored in one of the loop memories of the bin storage system, the IMS allows measurements of the differential of battery impedance to be calculated ( $dZ/dt$ ). The battery impedance differential ( $dZ/dt$ ) can in fact be utilised as a predictor of battery  
10 performance, and is particularly useful where a plurality of batteries can be compared against one another, as is the case in, for example, a telecommunications exchange standby battery power system. The IMS can measure  $dZ/dt$  for all batteries, or all cells, in a bank of batteries of the power system and, over a period of time for the data stored in the bin storage, determine which battery will be the first to fail. This is due to the performance of lead acid  
15 batteries in which it has been generally shown that of a plurality of batteries, that with the highest  $dZ/dt$  at any given time will be the battery to fail first of those plurality of batteries. This function can be achieved with the continuous monitoring and bin storage system of the IMS, but has been unfeasible in traditional battery measurement systems. In conjunction with other measured information as gathered and analysed by the expert system in IMS, the battery  
20 impedance time differential can be used as the basis of a run-time predictor during discharge.

As discussed hereinabove, the controlling software of the IMS is based on an owner-user model, and at the time of manufacture or installation certain parameters and settings of the IMS are required to be initialised by the "owner". These settings include details of the  
25 connectivity matrix 340 to instruct the controlling software in the selection of appropriate physical inputs for each desired measured parameter 350, and details of the association matrix 360 for determining the desired virtual parameters 370 from the measured parameters. The association matrix 360 will preferably also include stored indications of any desired scaling factors and units applicable to the virtual parameters. The owner is also responsible for  
30 initialising the data storage memory (the "bin memory") and the storage configuration

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parameters associated therewith, such as the measurement sampling rate and data storage interval for each of the averaging engines. Only the owner is entitled to reset the data storage memory to discard any saved data, but the stored data is not able to be edited - even by the owner. The configuration of the IMS can be changed by the owner using commands sent to the digital processing circuit 100 by way of the communications circuit 120 (Figure 12). Further, a plurality of IMS devices can be daisy-chained, even between different sites, so that the owner can broadcast configuration changes to multiple IMS controllers at once.

The user, on the other hand, has only limited access to the functions of the IMS. The main concern of the user is to be able to obtain access to the data stored in the IMS during monitoring, and this can be done on site or remotely through the communications circuitry 120. The user is not able to edit or erase the stored data. Certain exception conditions used by the IMS to determine when to raise an alarm or the like may be set or altered by the user, primarily those conditions which require to be varied from time to time depending upon prevailing conditions in the monitored system.

In the event that the IMS detects a change of environment, such as by disconnection from it's source of power or the like, when the IMS is powered up once again the controlling software changes the mode of operation. If a change of environment is detected the controller can no longer be certain that the configuration settings with which it has been programmed by the owner are applicable to the new environment, and thus to avoid the possibility of incurring any damage the IMS reverts to a "dumb" operation mode. In this mode the virtual parameter configurations programmed by the owner are ignored, and the IMS essentially reverts to a multiplexed voltmeter in which voltage levels are measured at each of the physical inputs at predetermined intervals, for example 1 second intervals. The binning memory procedure is not implemented and the measured voltage levels are merely stored as raw data in the memory. The IMS software does, however, allow the Owner or user to accommodate situations where only some component elements of the system being monitored are physically removed or changed in time (for example, replacement of a single battery cell) without loss of previously stored information about other elements of the system which are not changed.

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The foregoing detailed description of the present invention has been presented by way of example only, and is not intended to be considered limiting to the invention which includes every novel feature and novel combination of features herein disclosed.

- 5 Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

## CLAIMS:

1. A monitoring system for monitoring parameters of an apparatus, comprising:  
a plurality of inputs for receiving a plurality of electrical analog signals representative  
5 of parameters of said apparatus;  
a multiplexing circuit for multiplexing said analog signals into sequential analog input  
signals;  
an auto-ranging circuit for individually scaling each of said sequential analog input  
signals to within a predetermined range suitable for digital processing thereof;  
10 a signal converter for converting the scaled sequential analog input signals into  
respective digital signals; and  
digital processing means for storing and/or manipulating said digital signals.
2. A system as claimed in claim 1 wherein said multiplexing circuit comprises an array  
15 of photo-MOS elements.
3. A system as claimed in claim 2 wherein said photo-MOS elements are controlled by  
said digital processing means to perform a multiplexing function.
- 20 4. A system as claimed in claim 1 wherein said auto-ranging circuit comprises a plurality  
of auto-ranging photo-MOS elements.
5. A system as claimed in claim 4 wherein said auto-ranging circuit further comprises a  
plurality of resistive elements across which said sequential analog input signals are selectively  
25 applied by said auto-ranging photo-MOS elements.
6. A system as claimed in claim 5 wherein said plurality of resistive elements are used  
to provide voltages of selected proportions of one of said sequential analog input signals to  
said auto-ranging circuit, wherein respective said auto-ranging photo-MOS elements are  
30 coupled to one or more of said plurality of resistive elements to selectively generate an output



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within said predetermined range.

7. A system as claimed in claim 6 wherein said auto-ranging circuit comprises an analog signal amplifier circuit for increasing a voltage level of one of said sequential analog input  
5 signals to within said predetermined range.

8. A system as claimed in claim 7 wherein said auto-ranging circuit comprises a sample-and-hold circuit for smoothing changes in the respective magnitudes of said sequential analog input signals.

10

9. A system as claimed in claim 1 wherein the monitoring system is powered by a wide range switch-mode power supply.

10. A system as claimed in claim 1 wherein the monitoring system may be powered by a  
15 system which said monitoring system monitors.

11. A system as claimed in claim 9 wherein said power supply is adapted to automatically adjust to differing input voltage sources.

20 12. A system as claimed in claim 1, further including impedance measuring means for measuring the impedance of a circuit of said apparatus.

13. A method for monitoring parameters of an apparatus, comprising the steps of:  
receiving a plurality of electrical analog signals representative of parameters of said  
25 apparatus;  
multiplexing said analog signals into sequential analog input signals;  
scaling each of said sequential analog input signals to within a predetermined range suitable for digital processing thereof;  
converting the scaled sequential analog input signals into respective digital signals  
30 using signal converter means; and

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storing and/or manipulating said digital signals using digital processing means.

14. A method as claimed in claim 13 wherein said digital signals are representative of data sampled over a first time interval, and said step of storing and/or manipulating includes  
5 averaging a plurality of said digital signals over said first time interval to produce a first averaged data value.

15. A method as claimed in claim 14 wherein said step of storing and/or manipulating further includes averaging a plurality of said first averaged data values over a second time  
10 interval to produce a second averaged data value.

16. A method as claimed in claim 15 wherein said step of storing and/or manipulating further includes averaging a plurality of said second averaged data values over a third time interval to produce a third averaged data value.

15

17. A method as claimed in claim 16 wherein said step of storing and/or manipulating further includes averaging a plurality of said third averaged data values over a fourth time interval to produce a fourth averaged data value.

20 18. A method as claimed in claim 17, further including the step of storing a plurality of said first, second, third or fourth averaged data values in respective memory means.

19. A method as claimed in claim 13 wherein said step of multiplexing is performed by a multiplexing circuit comprising an array of photo-MOS elements.

25

20. A method as claimed in claim 19 wherein said photo-MOS elements are controlled by said digital processing means to perform said step of multiplexing.

21. A method as claimed in claim 13 wherein said step of scaling is performed by an auto-  
30 ranging circuit comprising a plurality of auto-ranging photo-MOS elements.

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22. A method as claimed in claim 21 wherein said auto-ranging circuit further comprises a plurality of resistive elements across which said sequential analog input signals are selectively applied by said auto-ranging photo-MOS elements.

5 23. A method as claimed in claim 22 wherein said plurality of resistive elements are used to provide voltages of selected proportions of one of said sequential analog input signals to said auto-ranging circuit, wherein respective said auto-ranging photo-MOS elements are coupled to one or more of said plurality of resistive elements to selectively generate an output within said predetermined range.

10

24. A method as claimed in claim 23 wherein said auto-ranging circuit comprises an analog signal amplifier circuit for increasing a voltage level of one of said sequential analog input signals to within said predetermined range.

15 25. A method as claimed in claim 24 wherein said auto-ranging circuit comprises a sample-and-hold circuit for smoothing changes in the respective magnitudes of said sequential analog input signals.

26. A method as claimed in claim 13, further including the step of measuring the  
20 impedance of a circuit of said apparatus.

27. A monitoring system, comprising:  
an input means for receiving at least one electrical signal input;  
a data acquisition means for obtaining first data values representing the at least one  
25 signal input repeatedly sampled at a first time interval;  
a first storage means for storing said first data values;  
a first averaging means for generating second data values representing averaged values  
of said first data values over a second time interval; and  
a second storage means for storing said second data values.

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28. A system as claimed in claim 27 wherein said monitoring system further includes at least one succeeding averaging means and at least one succeeding storage means, wherein each succeeding averaging means is arranged to generate succeeding data values over a succeeding time interval, representing average values of data values stored in a preceding storage means, and each succeeding storage means is arranged to store said succeeding data values.

29. A system as claimed in claim 27 wherein said second time interval is longer than said first time interval.

10

30. A system as claimed in claim 28 wherein each succeeding time interval is longer than a preceding time interval.

31. A system as claimed in claim 27 wherein said first and second storage means comprise circular memory means.

32. A system as claimed in claim 27 wherein said first and second storage means comprise a FIFO buffer.

20 33. A system as claimed in claim 27 wherein the monitoring system is powered by a wide range switch-mode power supply.

34. A system as claimed in claim 27 wherein the monitoring system may be powered by a system which said monitoring system monitors.

25

35. A system as claimed in claim 33 wherein said power supply is adapted to automatically adjust to differing input voltage sources.

36. A monitor for monitoring a battery, comprising:

30 battery impedance means for generating sampled impedance measurements of the

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impedance of said at least one battery at predetermined sampling intervals; and

storage means for storing digital representations of said sampled impedance measurements in a plurality of memory means, each memory means being adapted to store representations of said sampled impedance measurements generated at respective different  
5 time intervals.

37. A monitor as claimed in claim 36 wherein said digital representations are used to generate a measure of a time differential of the impedance of said at least one battery.

10 38. A monitor as claimed in claim 37 wherein said time differential is a measure of the change in impedance of said at least one battery over time, and said time differential is indicative of a likelihood of failure of said at least one battery.

39. A method of monitoring a plurality of batteries or cells, comprising:  
15 repeatedly measuring an impedance of each of said plurality of batteries or cells over a predetermined time interval;  
recording digital representations of the measured impedances; and  
determining, using said digital representations, a measure of a time differential of the impedance of each of the plurality of batteries or cells.

20

40. A method as claimed in claim 39 wherein said time differential is a measure of the change in impedance of one of said batteries or cells over time, and further including the step of predicting, based on a plurality of respective said measures, a likelihood of failure of said battery or cell.

25

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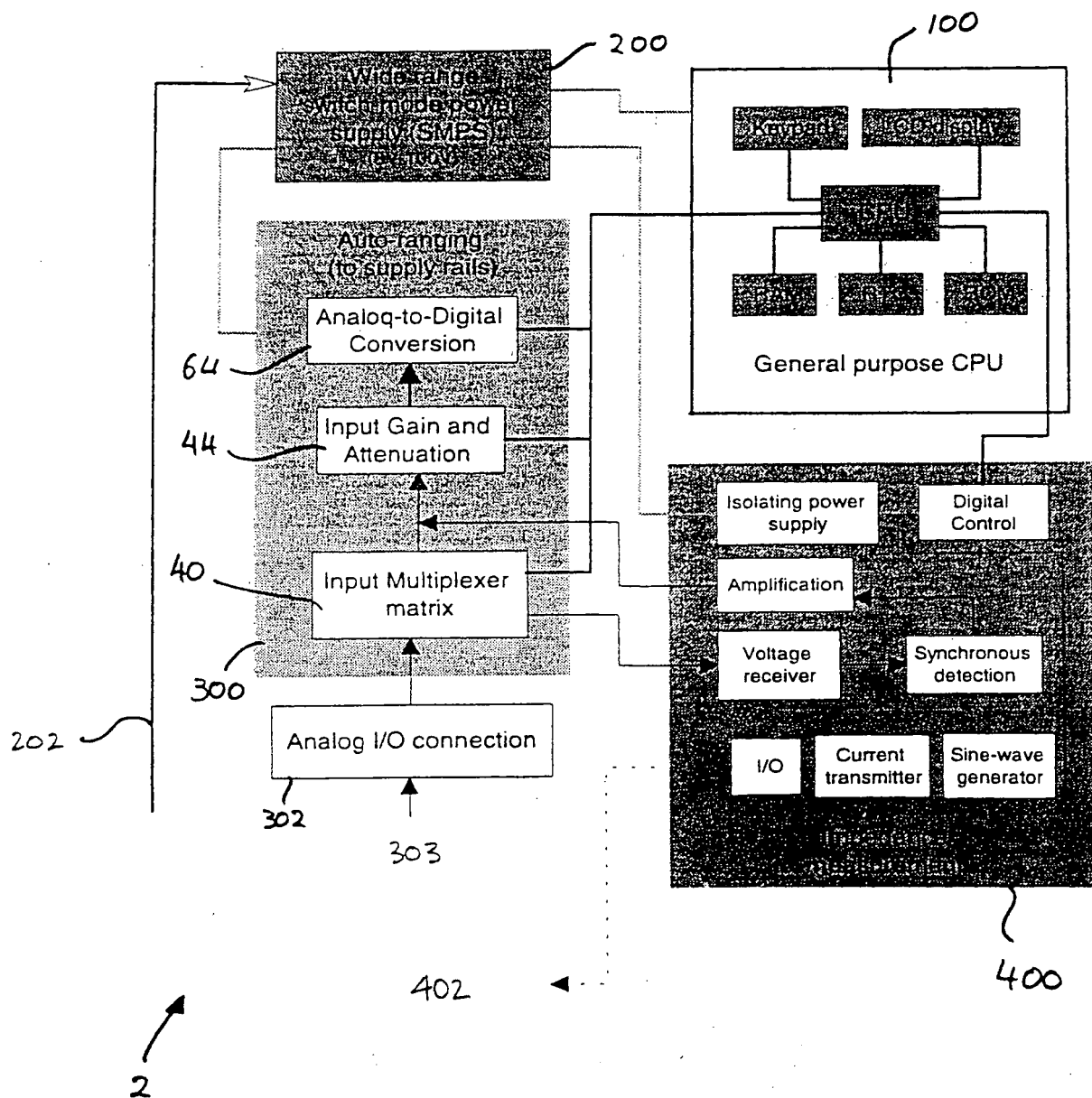


FIGURE 1

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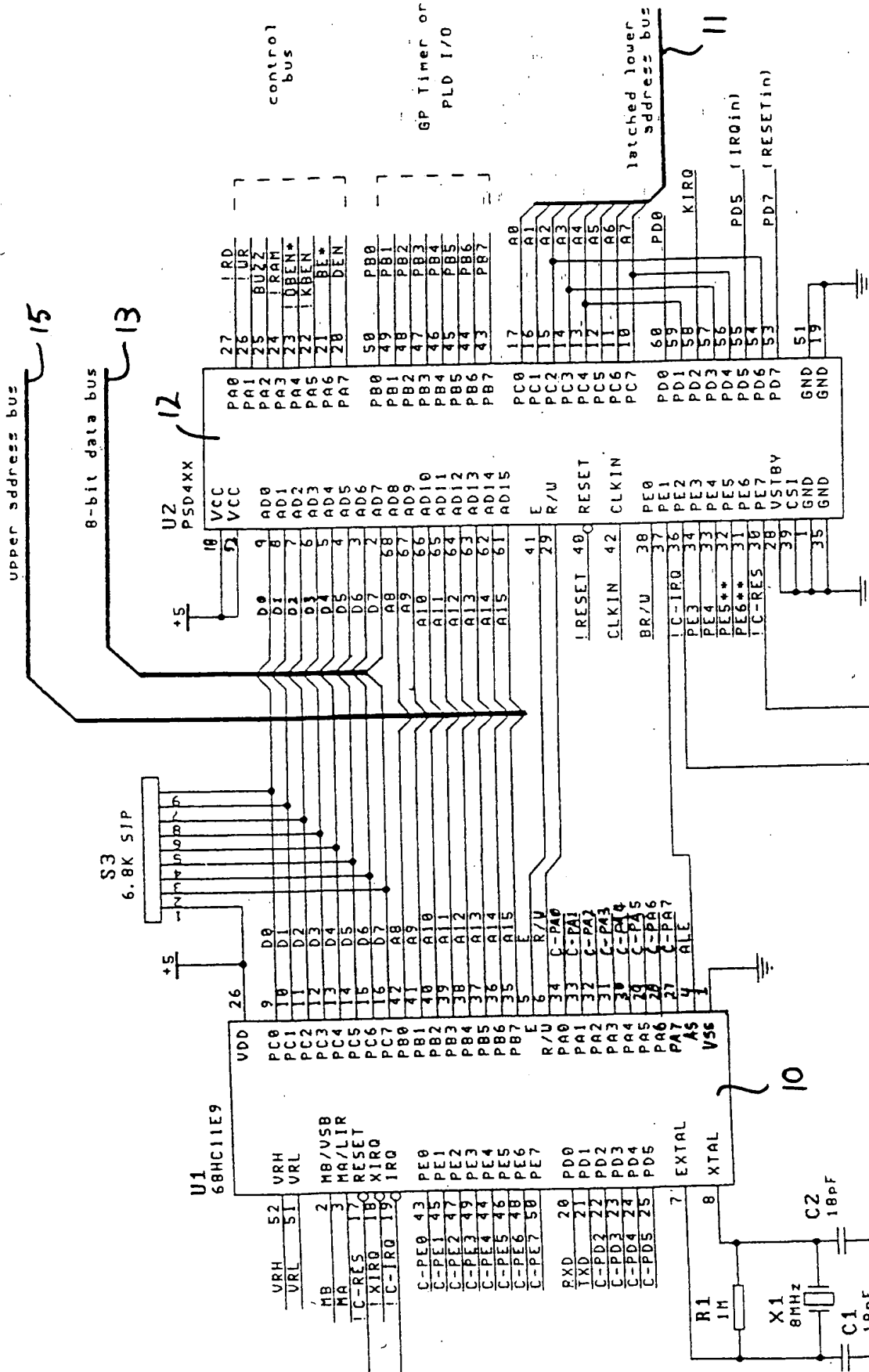


FIGURE 2

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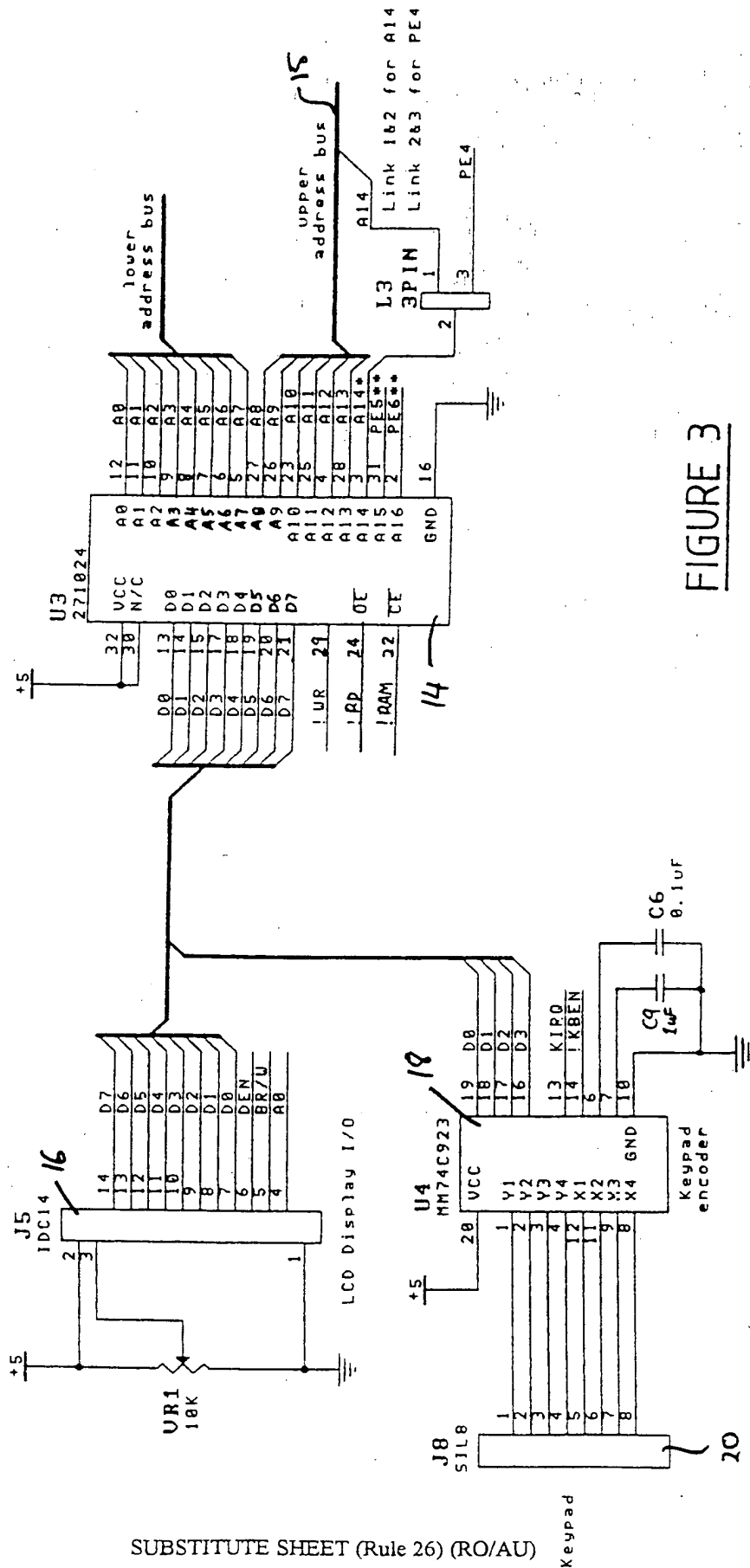


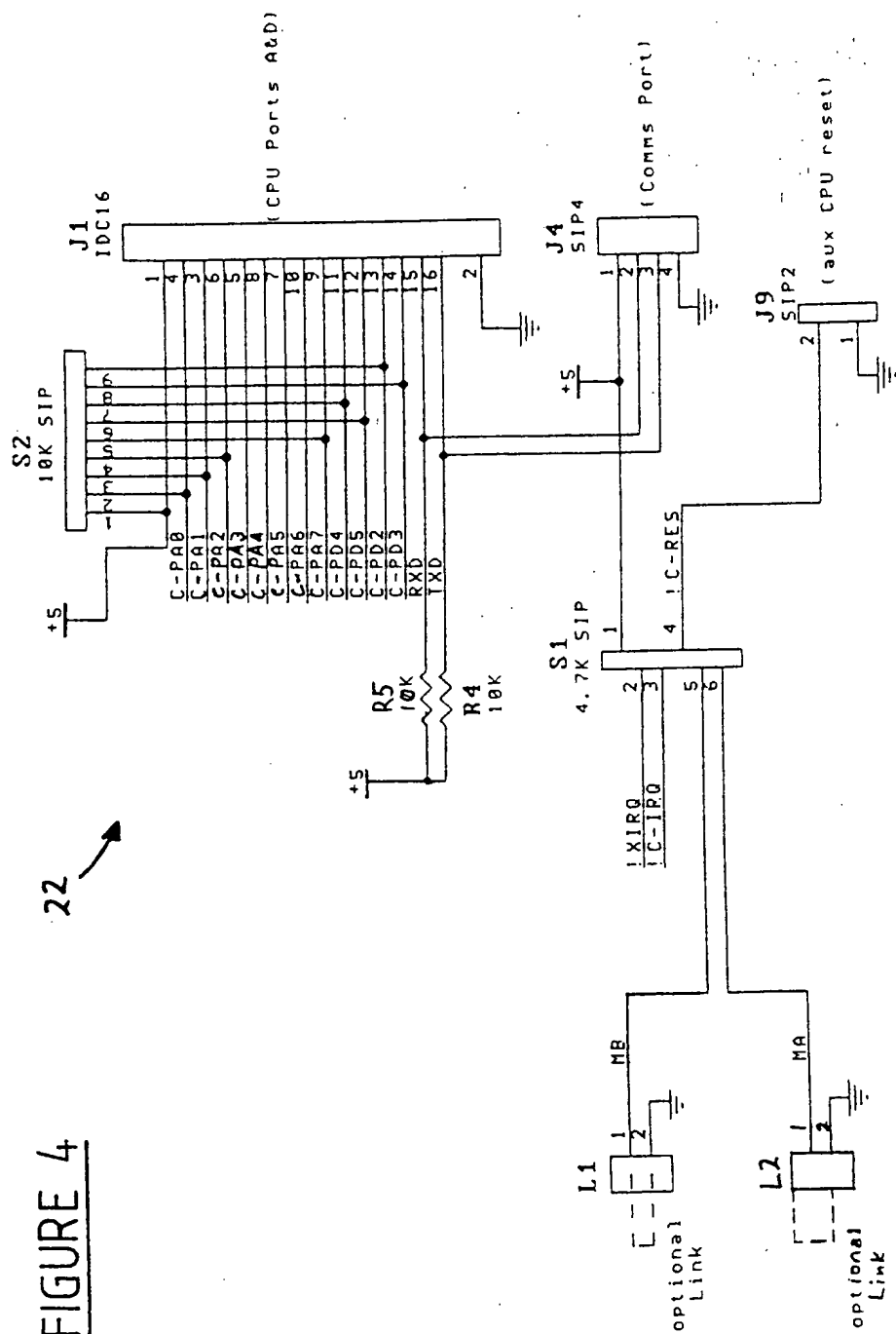
FIGURE 3



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FIGURE 4

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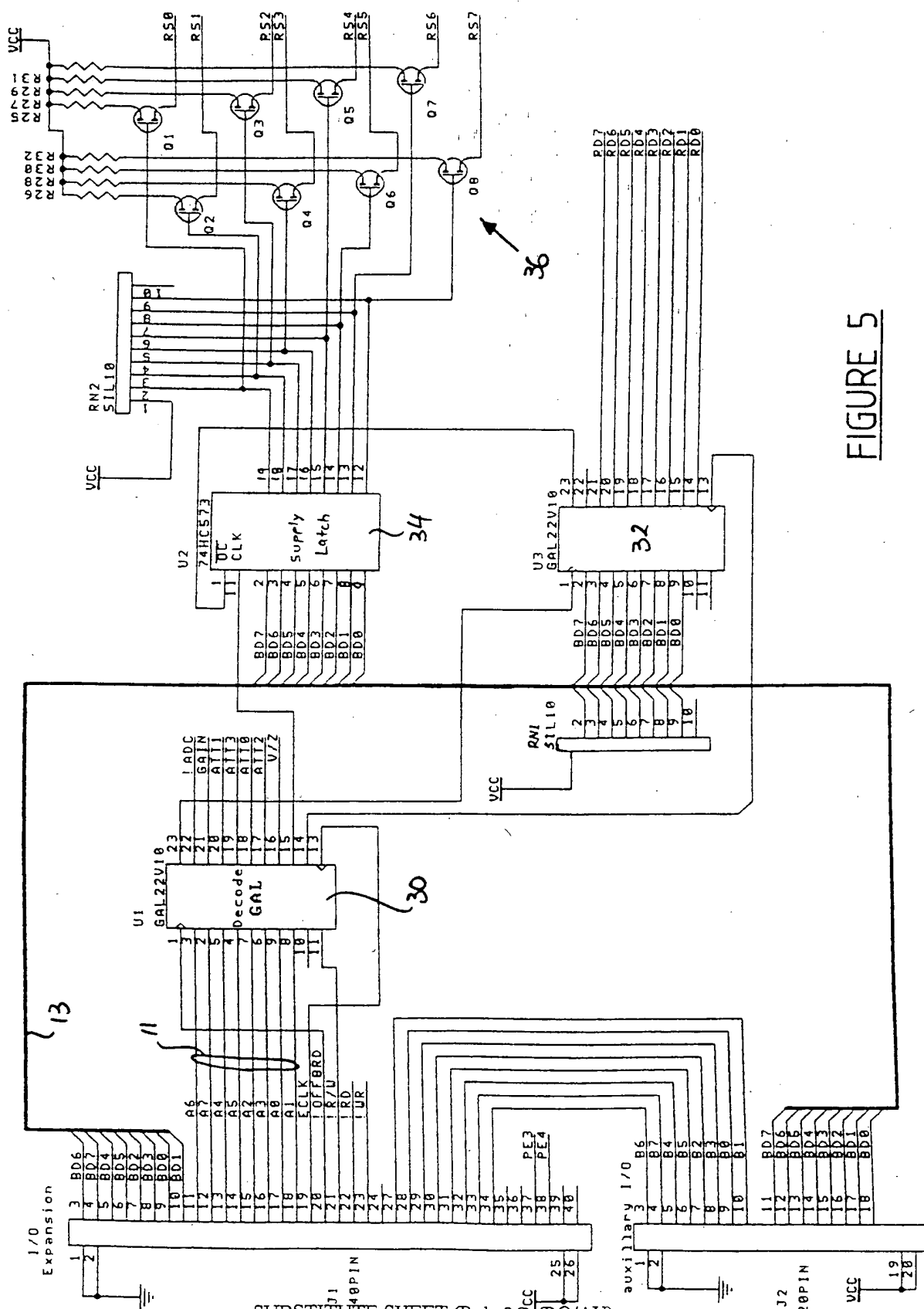


FIGURE 5

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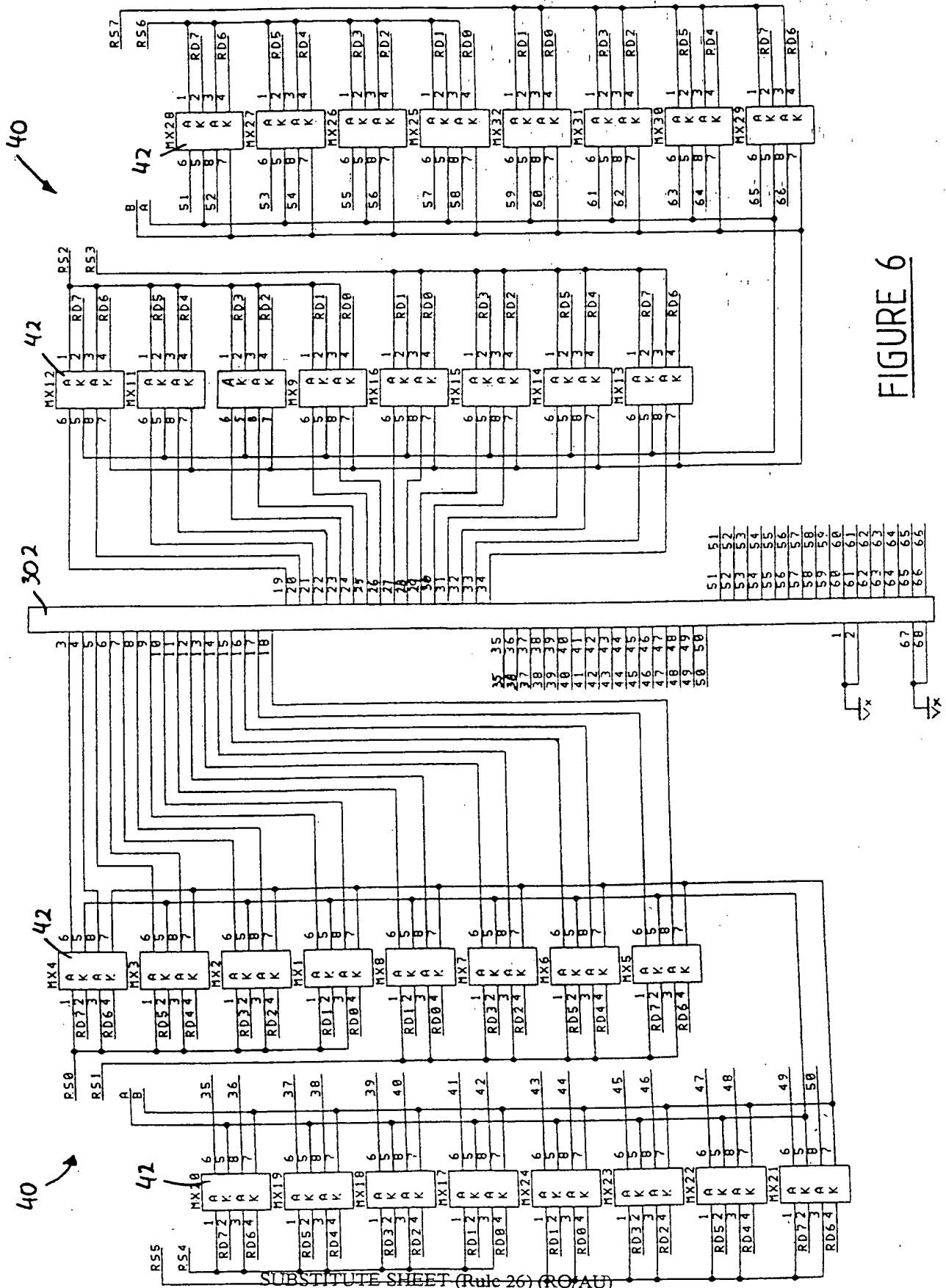


FIGURE 6

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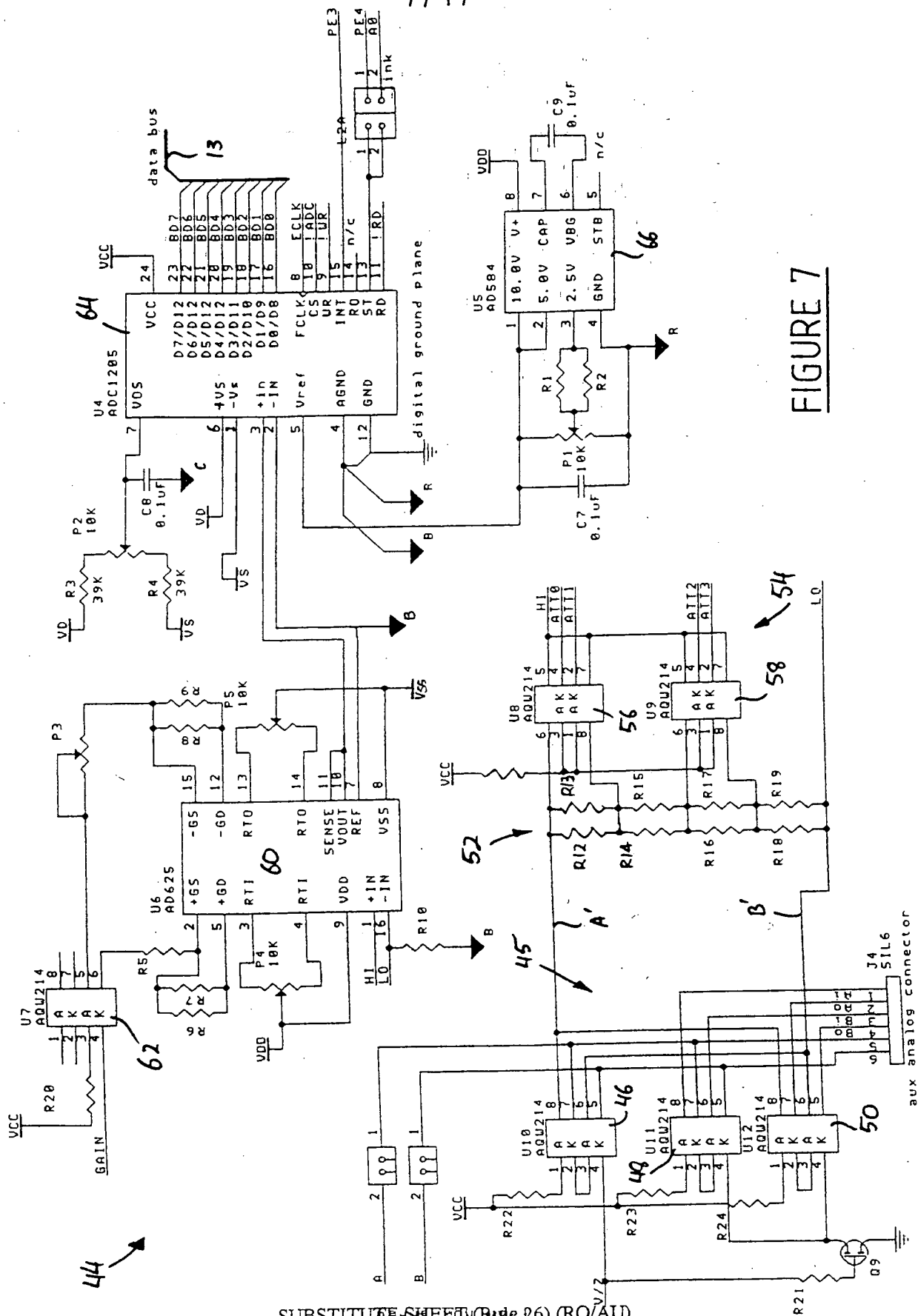


FIGURE 7

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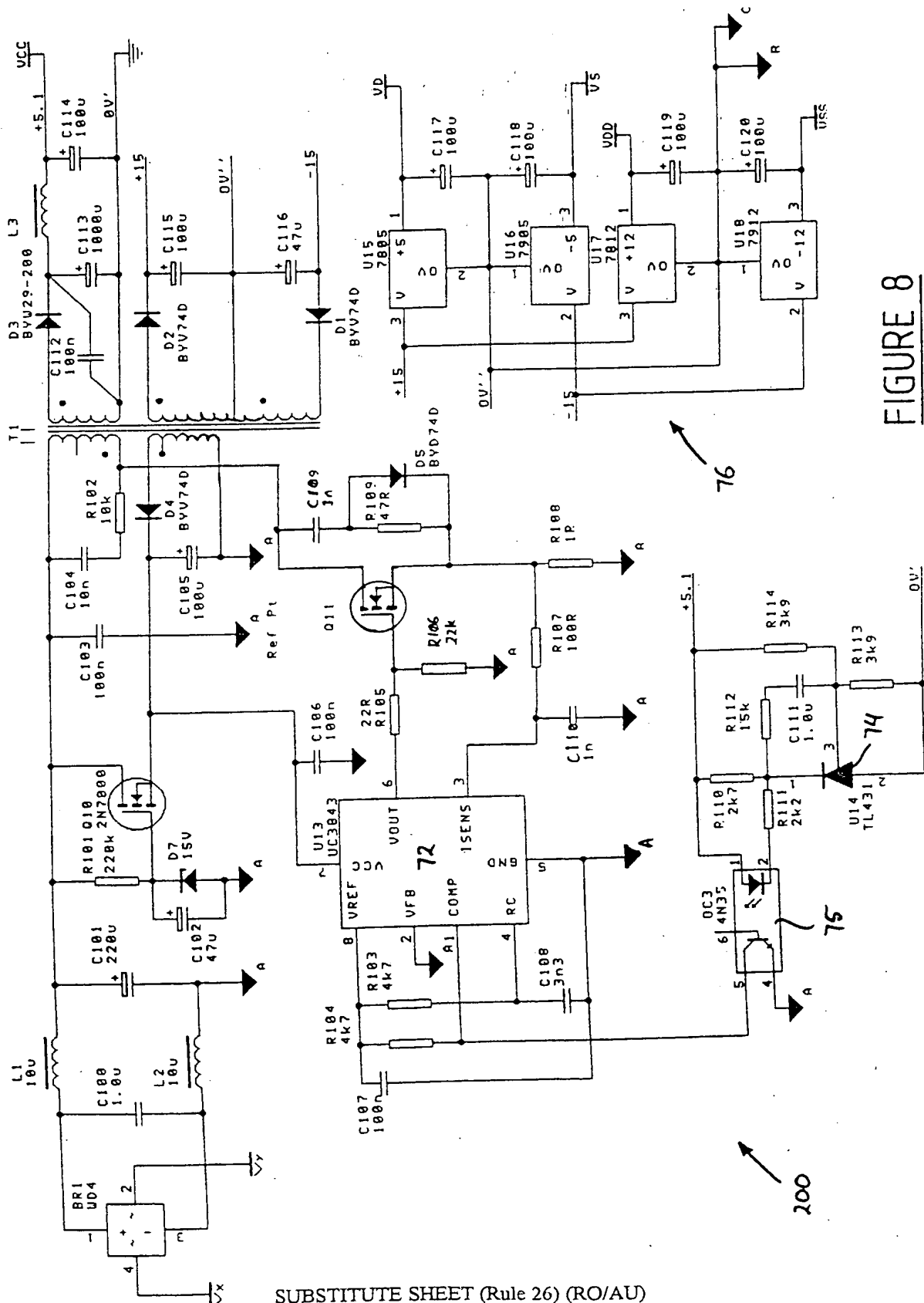


FIGURE 8

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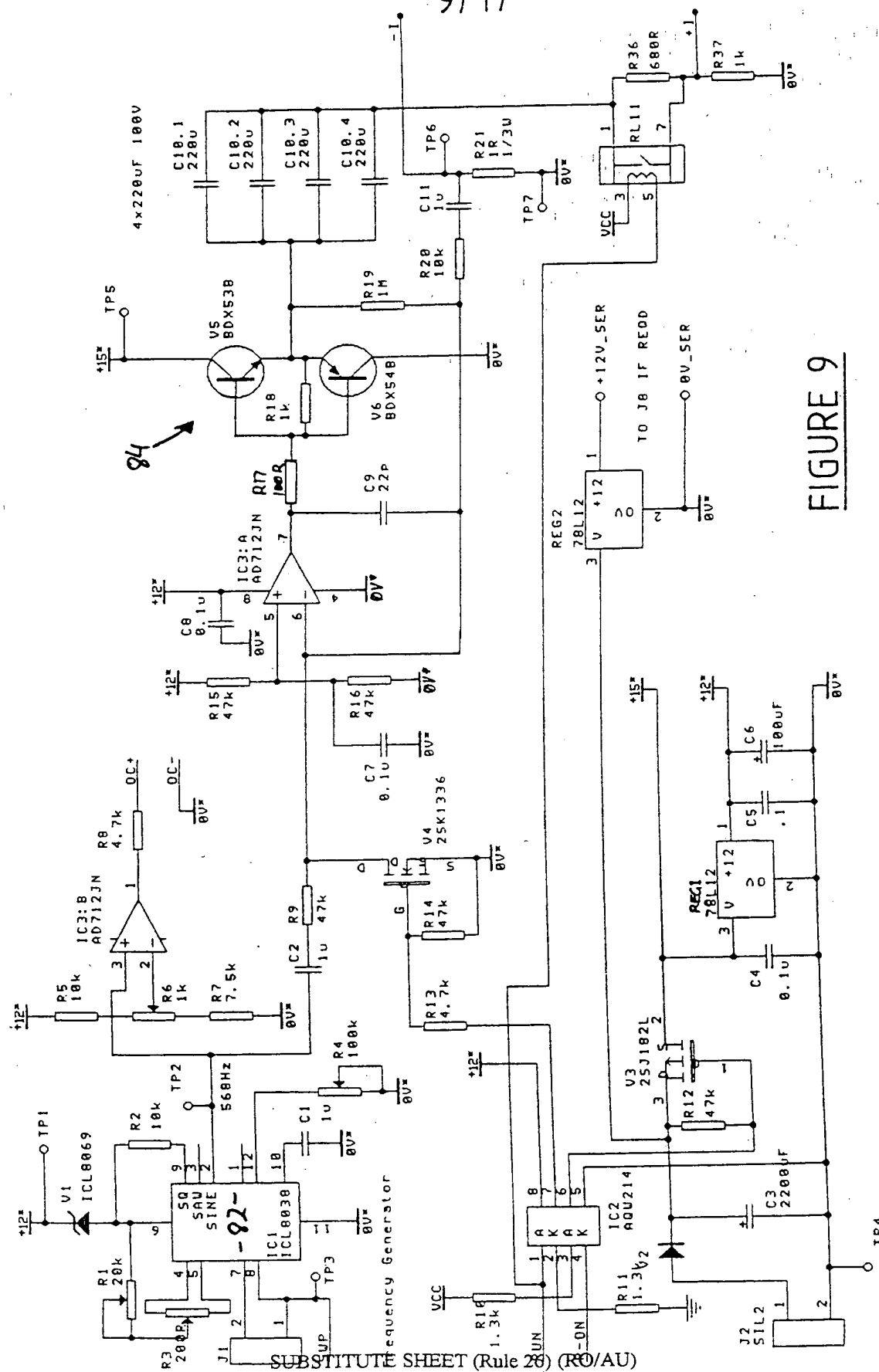
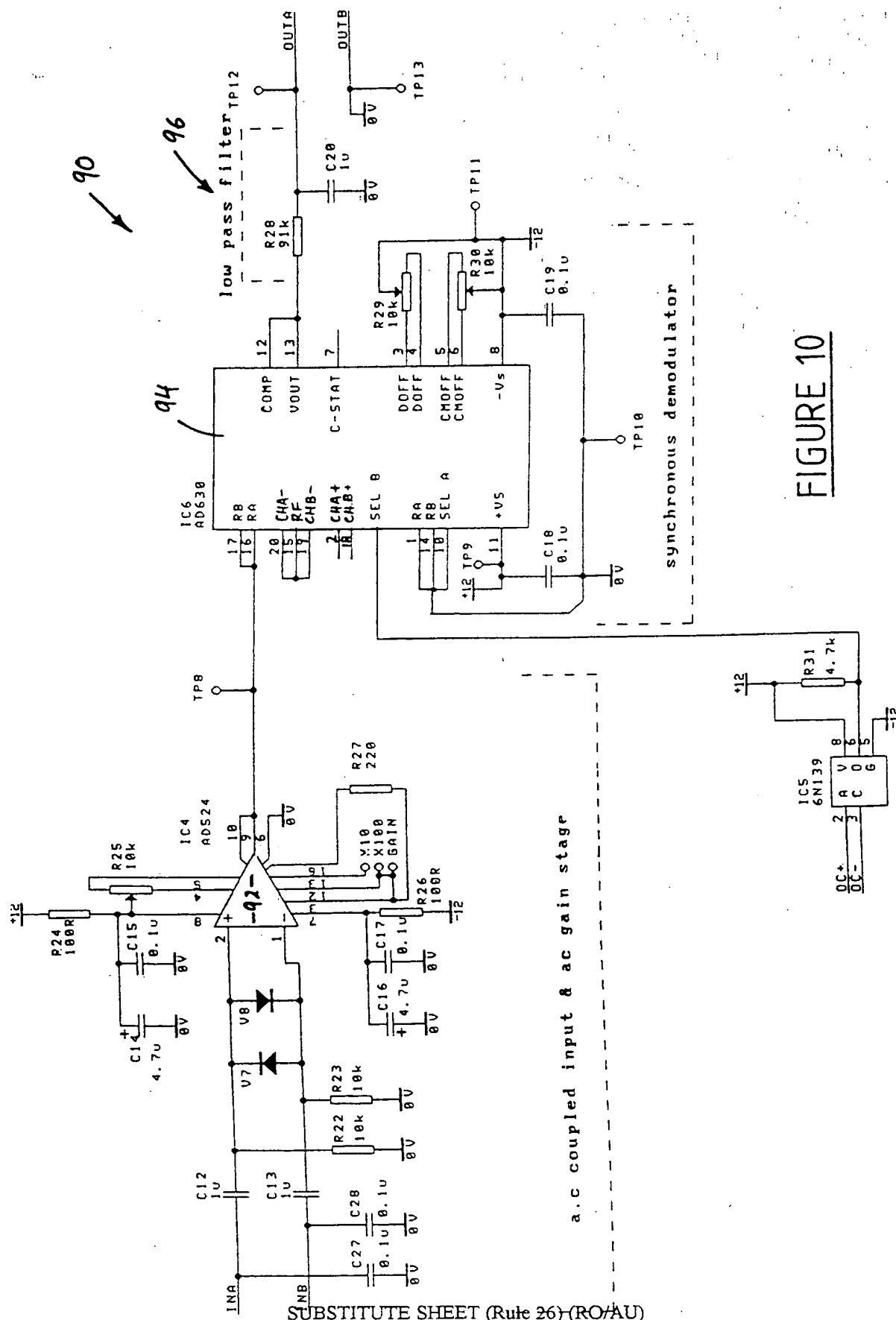


FIGURE 9

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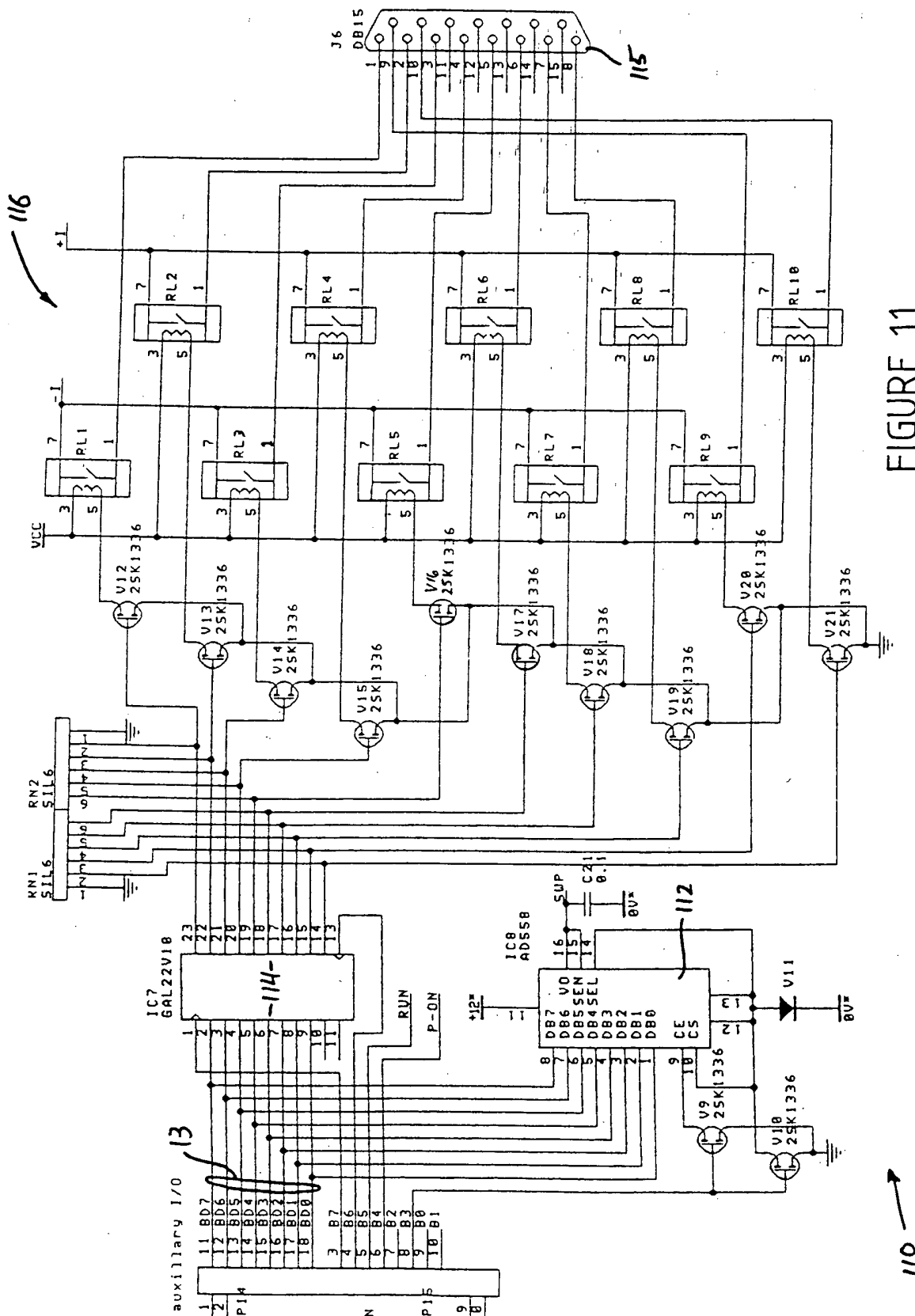


FIGURE 11



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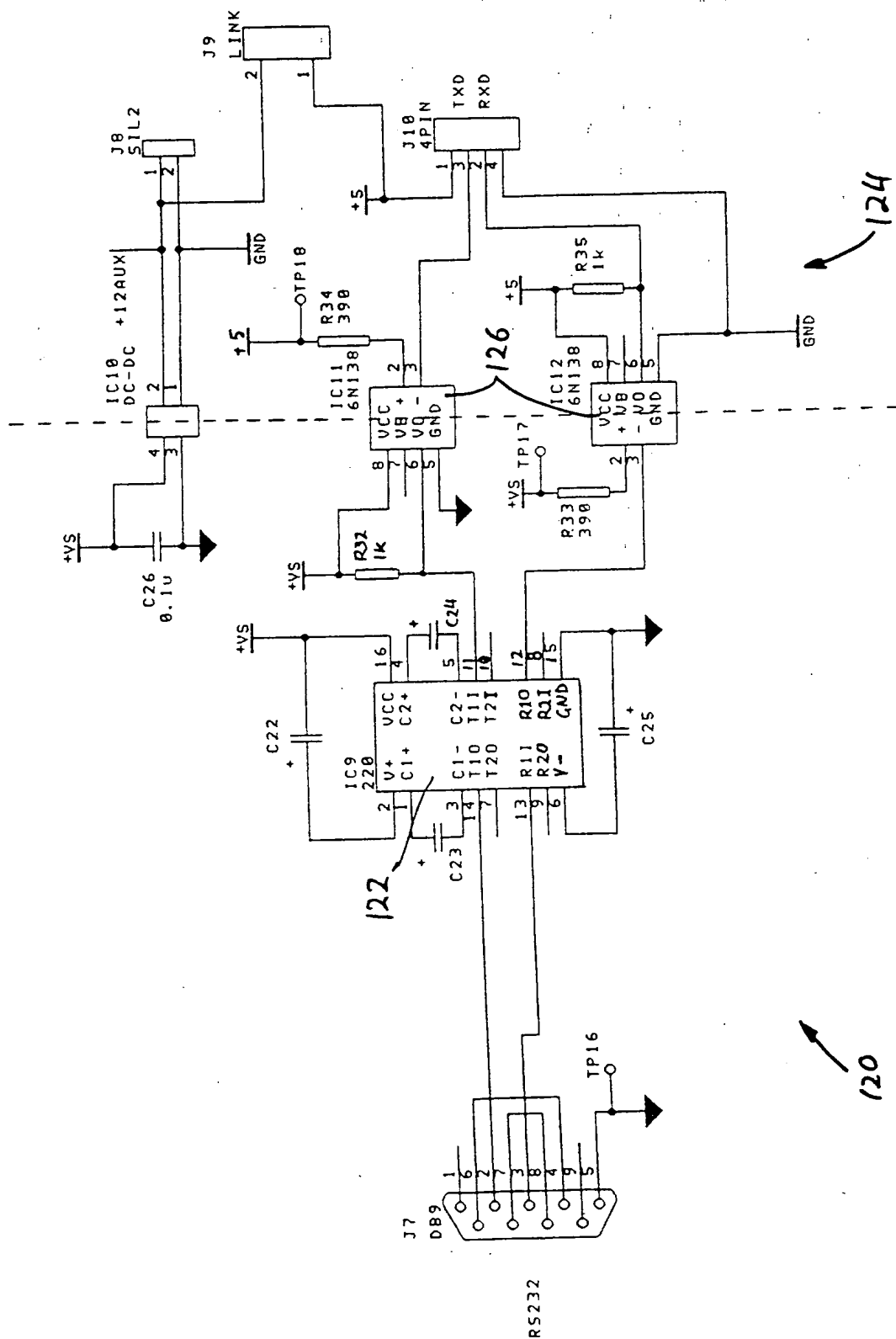


FIGURE 12

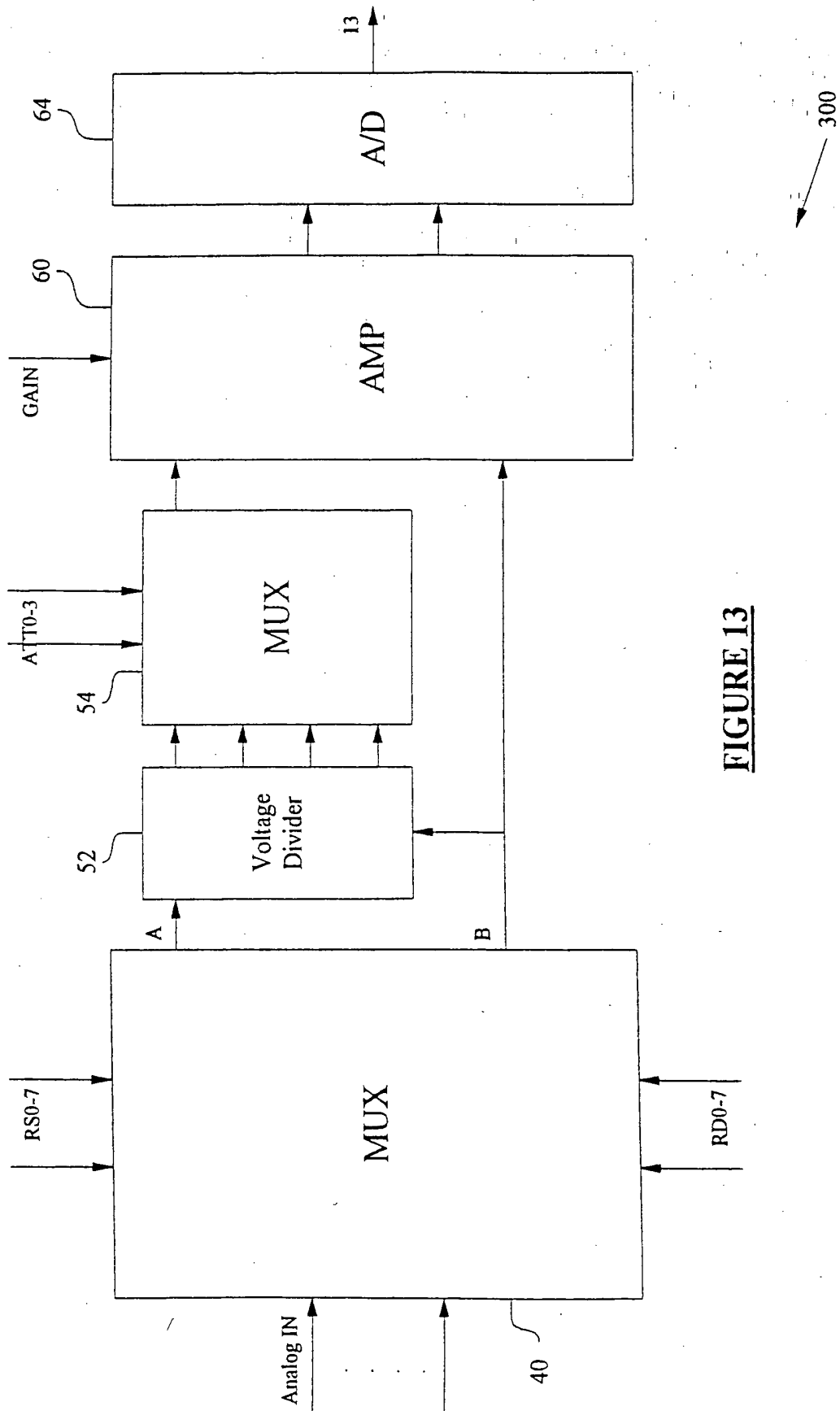
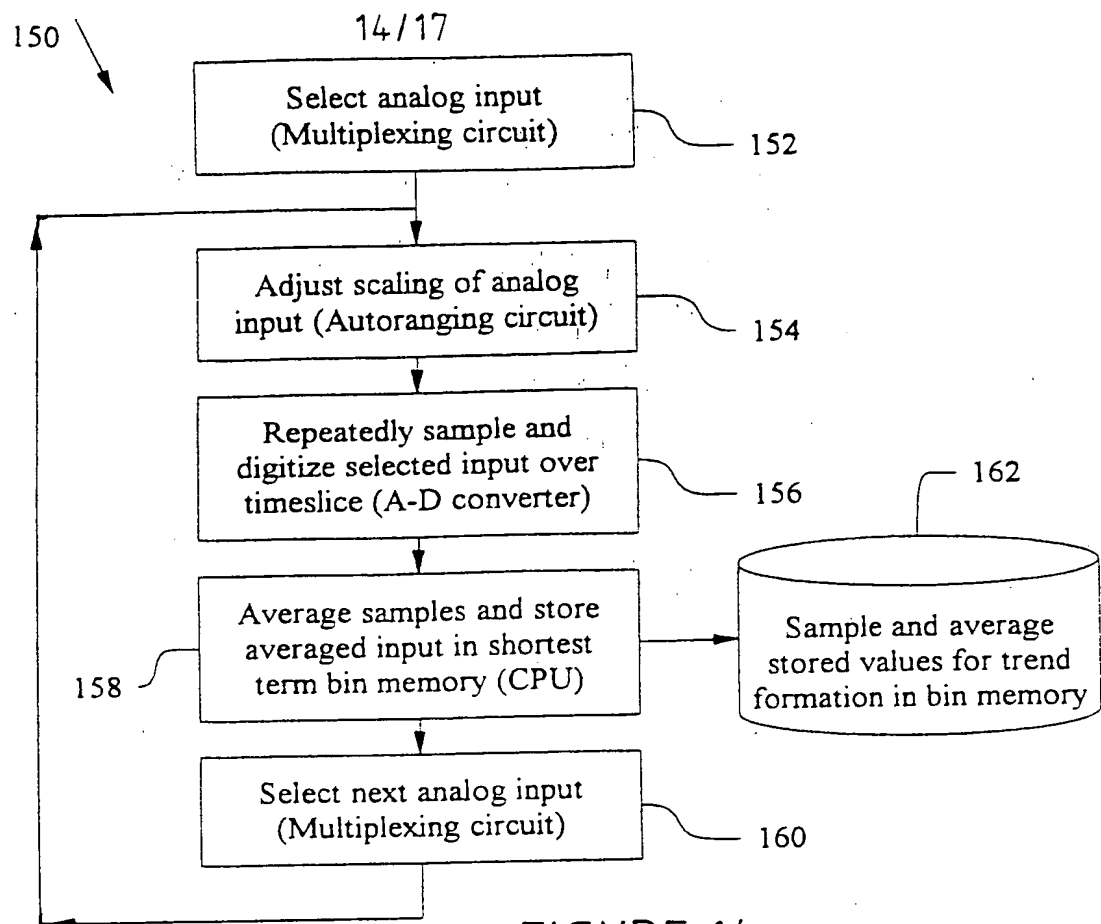
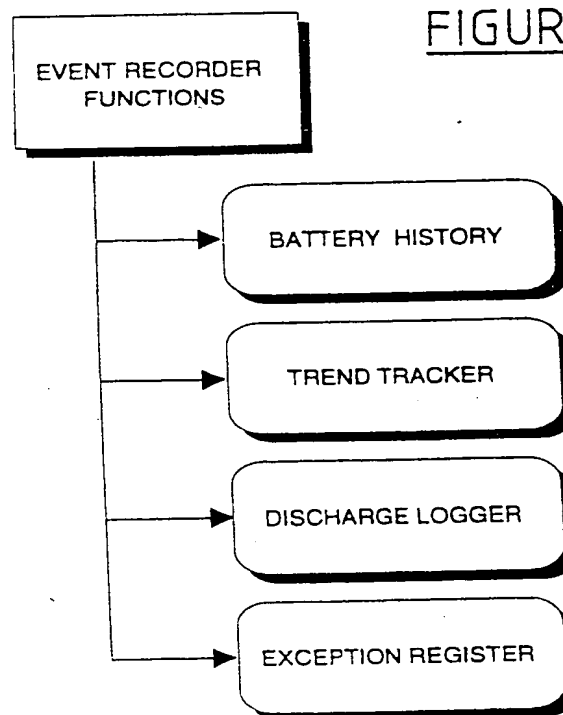


FIGURE 13

FIGURE 14

15/17

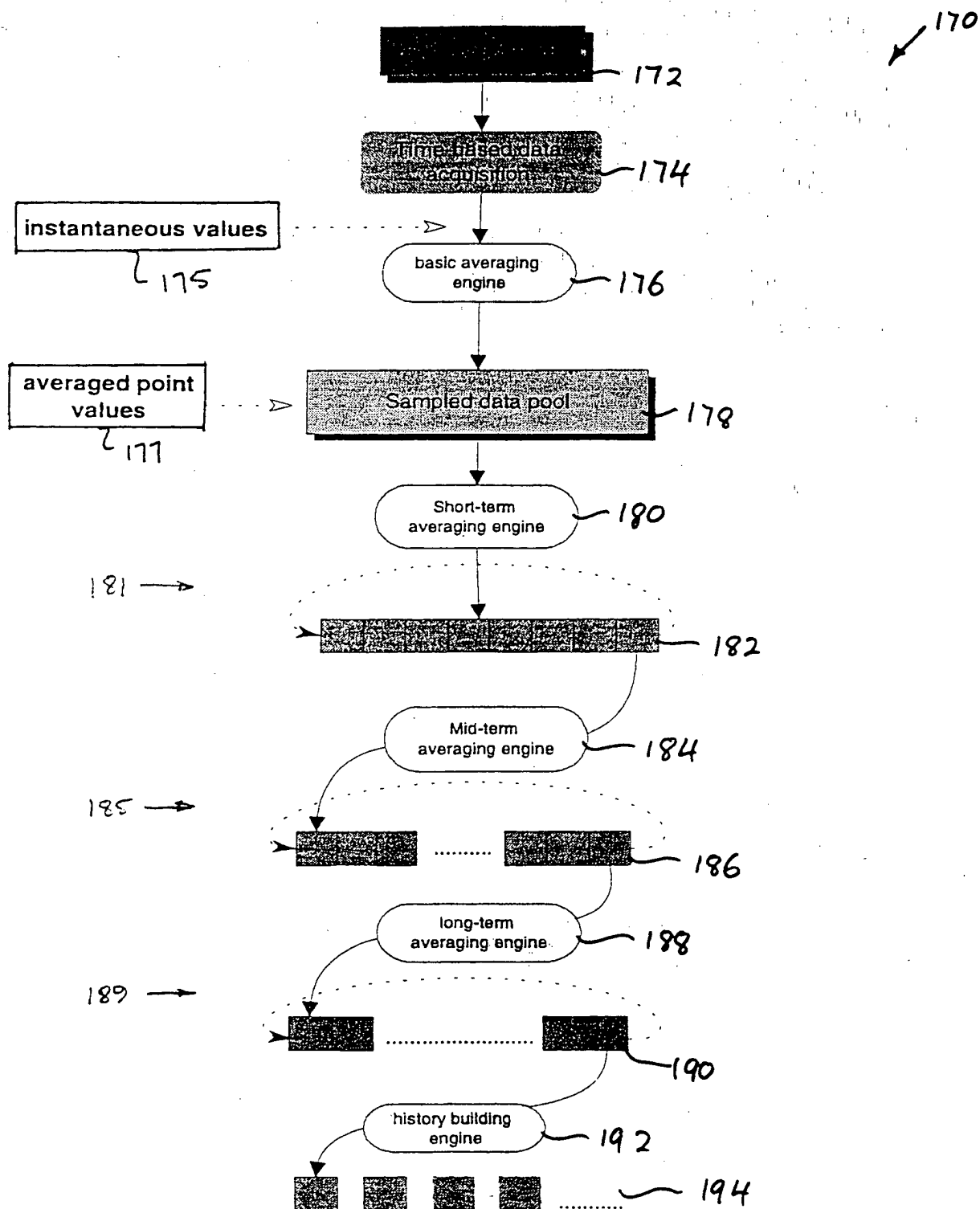
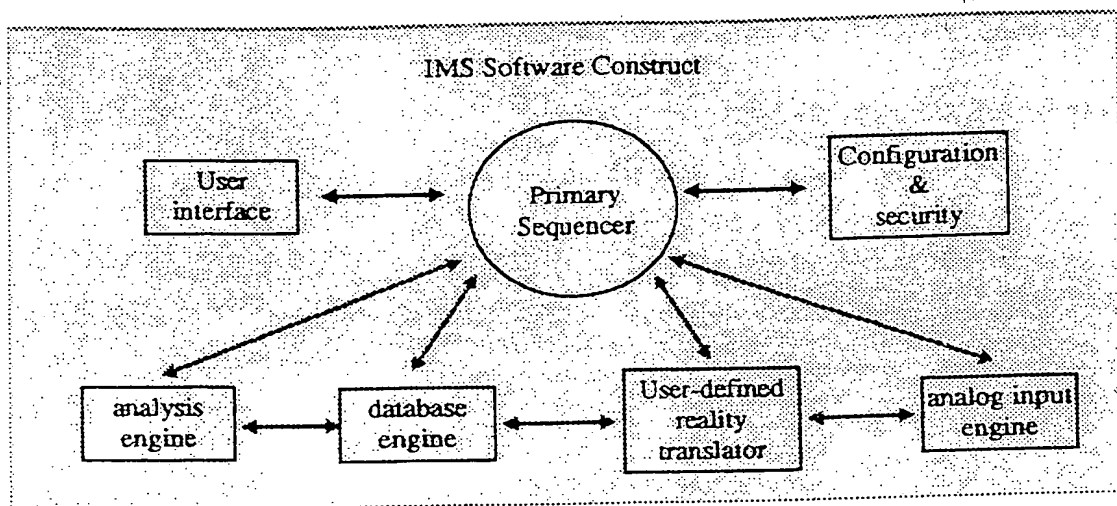
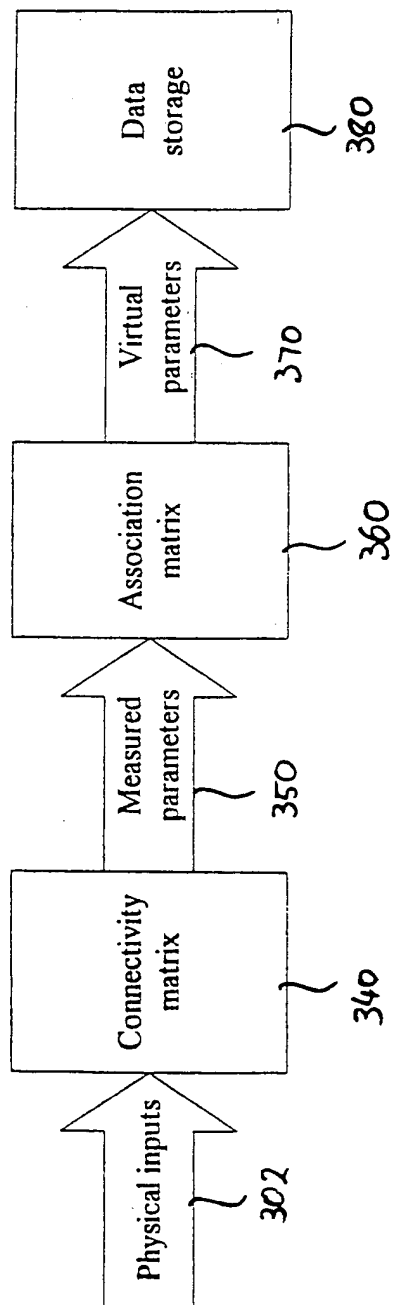


FIGURE 15

16/17

FIGURE 17

17/17

Figure 18

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/AU 98/01073

<b>A. CLASSIFICATION OF SUBJECT MATTER</b>		
Int Cl <sup>6</sup> : G01R 27/02, 31/36; G06F 17/40; H01M 10/48		
According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b>		
Minimum documentation searched (classification system followed by classification symbols) IPC: H01M, G01R, G05B, G06F		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched AU: IPC as above		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) WPAT : (MONITOR: or CONTROL or TEST: or CHECK:) AND ANALOG: AND DIGITAL AND MULTIPLEX: AND CONVERT: AND (STOR: or MEMORY or MANIPULAT:) JAPIO : same as above		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 94/13197 A1 (SIEMENS MEDICAL SYSTEMS INC) 23 June 1994 whole document whole document	1,7,13,25-27 8-12,14-18,29,31-36
X	Derwent WPAT Online Abstract Accession No: 92-081152/11 Class T01 DE 4027898 A (BRUHN, A) 5 March 1992 Abstract	1,13
X Y	US 5062101 A (DEJEWSKI) 29 October 1991 whole document whole document	1,7,13,25-27 8-12,14-18,29,31-36
<div style="display: flex; justify-content: space-between;"> <span><input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C</span> <span><input checked="" type="checkbox"/> See patent family annex</span> </div>		
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# INTERNATIONAL SEARCH REPORT

International application No.  
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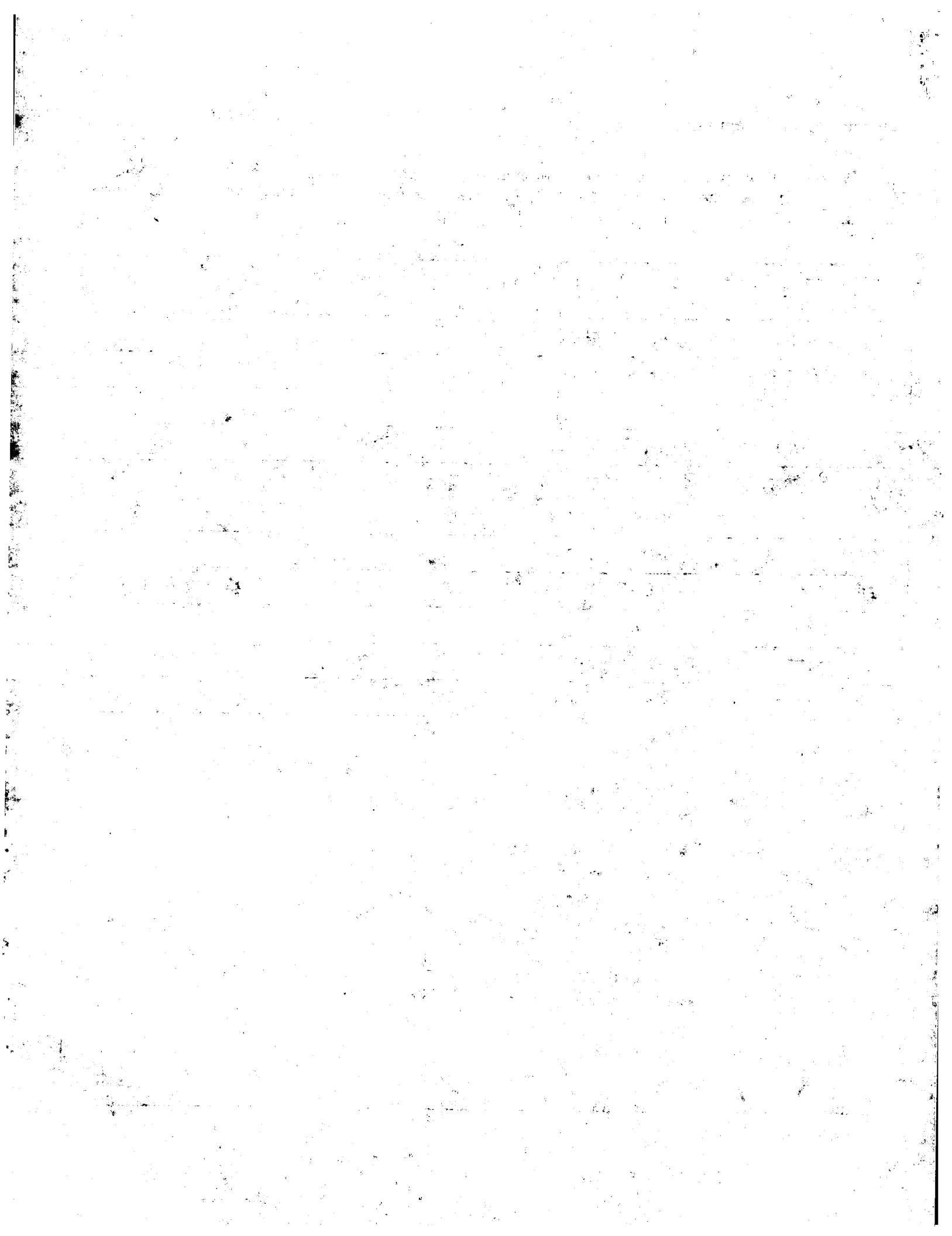
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 0277006 A2 (WESTINGHOUSE ELECTRIC CORPORATION) 3 August 1988 whole document	1,7,8,13,25-27
	whole document	8-12,14-18,29,31-36
X Y	GB 2188806 A (BURR-BROWN LIMITED) 7 October 1987 whole document	1,7,8,13,25-27
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Y	Derwent WPAT Online Abstract Accession No: 86-114072/18, Class T01, T02, DE 3527952 A (INST FUR LEICHTBAU & EKO) 24 April 1986 Abstract	1,8,13,25
X Y	EP 147239 A2 (KABUSHIKI KAISHA ISHIDA KOKI SEISAKUSHO) 3 July 1985 whole document	1,7,13,25-27
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	whole document	8-12,14-18,29,31-36



## Information on patent family members

PCT/AU 98/01073

Patent Document Cited in Search Report				Patent Family Member			
WO	94/13197	EP	673224				
DE	4027898	NONE					
US	5062101	NONE					
EP	277006	JP	1210825	US	5005142		
GB	2188806	DE	3711216	FR	2596889	JP	62242261
		US	4918647				
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EP	147239	AU	37148/84	JP	60142215	US	4790398
NL	8301510	NONE					
EP	110794	FR	2537303				
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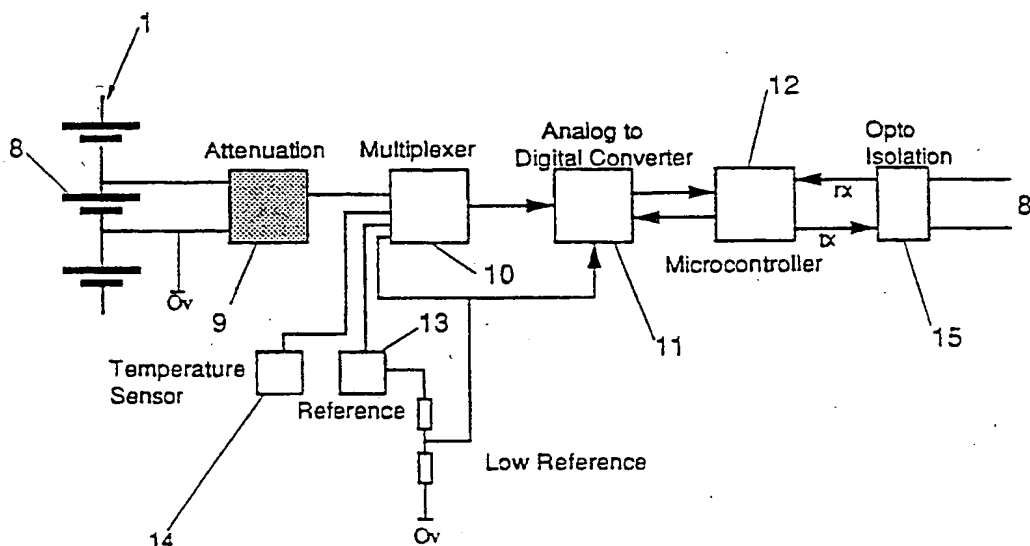




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>H02H 7/18, 7/22, 1/06, H02J 7/00</b>		A1	(11) International Publication Number: <b>WO 99/27628</b>
			(43) International Publication Date: 3 June 1999 (03.06.99)
(21) International Application Number: PCT/NZ98/00168 (22) International Filing Date: 19 November 1998 (19.11.98) (30) Priority Data: 329216 20 November 1997 (20.11.97) NZ (71) Applicant (for all designated States except US): BATTERY TECHNOLOGY LIMITED [NZ/NZ]; 2 Rothwell Avenue, Albany, Auckland (NZ).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).	
(72) Inventors; and (75) Inventors/Applicants (for US only): HECTORS, Antonius, Cornelis [NL/NZ]; 3 Tempo Place, Torbay, Auckland (NZ). GUY, Jonathan, Andrew [NZ/NZ]; 3 Dulwich Place, East Tamaki, Auckland (NZ). (74) Agents: CALHOUN, Douglas, C. et al.; A.J. Park & Son, Huddart Parker Building, 6th floor, Post Office Square, P.O. Box 949, Wellington 6015 (NZ).		Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.	

(54) Title: BATTERY MONITORING SYSTEM



## (57) Abstract

An electronically controlled system for monitoring a battery bank, which has associated with each battery or small group of batteries or cells a measurement module which among other things measures the cell voltage and cell temperature, digitally encodes and serially transmits these values via an isolated bus to a central processing unit (CPU) which stores and analyses the values and provides an indication of the status of each battery and produces alarms when appropriate. Each measuring module will be kept in close physical proximity to the batteries it measures such that the temperature measurement requires no extra outboard circuitry and electrical isolation between the monitoring system and the battery voltage is provided as close to each battery cell as possible. A number of measurement modules may be connected to common buses and each central processing unit may receive inputs from more than one bus.

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## BATTERY MONITORING SYSTEM

### TECHNICAL FIELD

This invention relates to a system for monitoring a bank of batteries.

### BACKGROUND ART

5 Batteries, or more often banks of batteries, are often used as standby power supplies. When the mains are removed or are not present such standby batteries will take the load. Batteries may also be used for backup and starting a backup generator.

Batteries have failure modes and reliability problems. This means they must be continually monitored in these applications. Monitoring will determine the capacity and  
10 the health of a battery or battery bank. This information provides an indication as to how long a battery system will function when the mains are out.

A battery may be monitored by measuring the voltage while under charge. Several failure modes can be detected.

More can be learnt about the state of a battery or battery bank by discharging the  
15 battery or battery bank with a constant current or constant power load. By discharging a bank the capacity of the bank can be determined and most other battery failure modes will be detected. Battery voltage and temperature indicate the health of the battery under discharge conditions. By discharging a bank according to the battery manufacturer specifications a determination can be made whether batteries are still  
20 within specification.

An example of a known battery monitoring system is disclosed in US Patent 4484140. In that patent a digital device monitors the voltage across each battery sequentially by using relays to switch one cell at a time across a common two line bus which forms the input to an analogue-to-digital converter. An isolation amplifier is  
25 used at the input of the analogue-to-digital converter. Such systems have the disadvantage that the bus will be long with any sizeable bank of batteries and will not be isolated. It will be appreciated that the DC potential between either bus line to ground may be very high. Further, such a system does not measure battery temperature.

### DISCLOSURE OF INVENTION

30 It is an object of the present invention to provide a battery monitoring system which goes some way towards overcoming the abovementioned disadvantages.

Accordingly in one aspect the present invention consists in a battery measuring module for a system for monitoring a plurality of batteries wherein said measuring module is associated with and measures parameters of one or more of a small number of physically proximate batteries, said measuring module comprising:

5       at least one analogue input port which in use is connected to at least one battery,  
      an analogue-to-digital converter connected to said at least one input port which  
      produces digital values proportional to the voltage on said at least one input port,  
      a device which stores said digital values, and  
      a digital output port,

10       said device presenting said digital values in serial form at the digital output port.

In a second aspect the invention consists in a monitoring system for a bank of batteries comprising:

      a digital central processing unit which is capable of storing and processing digital  
      parameters for each battery in the bank, said central processing unit having one or more  
15       serial input-output ports,

      one or more data buses, each connected to a respective serial input-output port on  
      said central processing unit,

      and, connected to and in association with one or more of a small number of  
      physically proximate batteries in said bank, a measuring module which may be polled  
20       by said central processing unit, said measuring module including:

      at least one analogue input port which in use is connected to at least one battery,  
      an analogue-to-digital converter connected to said at least one input port which  
      produces digital values proportional to the voltage on said at least one input port,  
      a device which stores said digital values,  
25       and a digital input-output port,

      said device presenting said digital values in serial form at the digital input-output  
      port upon receipt of a polling signal at said port,

      said digital input-output port of each measuring module being connected to said  
      data bus or one of said data buses.

## 30       BRIEF DESCRIPTION OF THE DRAWINGS

The preferred form of the invention will now be described with reference to the

accompanying drawings in which;

Figure 1 is a block diagram of a battery monitoring system according to the present invention,

Figure 2 is a block circuit diagram of a measuring module for a single battery,

5 Figure 3 is a waveform diagram illustrating the operation of the battery measurement module,

Figure 4 is a block diagram of a measuring module for a plurality of batteries with the voltages input through a multiplexer, and

10 Figure 5 is a block diagram of a measuring module for a plurality of batteries with the voltages input through a resistive divider network.

### **BEST MODE FOR CARRYING OUT THE INVENTION**

An overview of a battery monitoring system according to the present invention is shown in Figure 1. A battery bank 1, which may contain a number of batteries, has associated with a small group, preferably four, of batteries or cells a measurement  
15 module 2 which among other things measures the cell voltage and cell temperature, converts the values into digital form and supplies these values in serial form via a bus 3 to a central processing unit (CPU) 4 which stores and analyses the values and provides an indication of the status of each battery and produces alarms when appropriate. A number of measurement modules 2 may be connected to common buses and each  
20 central processing unit 4 may receive inputs from more than one bus. The communication protocol from each measurement module 2 to each central processing unit 4 will be described later.

Central processing units may be networked by an RS485 serial interface and may optionally supply data to a personal computer 6 for further analysis via an RS232 serial  
25 interface 7.

In more detail the monitoring system works as follows. The measurement module 2 connected to each battery measures the battery voltage. The measurement module also measures a reference voltage inside the module along with the battery temperature. It waits for a request from the CPU 4 to transmit this information on the isolated  
30 measurement module serial bus 3.

The CPU 4 converts the values that the measurement module transmits to a

calibrated voltage. The calibration constants for each connected measurement module are stored at the CPU. There is no theoretical limit on the number of measurement modules that can be connected to a measurement module bus but the number connected does affect the sample speed. For practical reasons the present system has a maximum of 10 modules per bus delivering 5 samples per second.

### Operation of Measurement Module

In the first embodiment each measurement module 2 is connected to a single battery 8 and may be external to the battery or integrated with it as shown in Figure 2. The battery voltage is attenuated 9 by a voltage divider and supplied to the analogue multiplexer 10. The internal reference voltage 13 and the output of temperature sensor 14 are also inputs to the analogue multiplexer 10 and thus are also converted by the analogue-to-digital converter.

Each signal is then converted to a time proportional to the voltage by an analogue-to-digital converter 11 and micro-controller 12. Figure 3 shows the timing diagram of the single slope analogue-to-digital conversion process implemented by the analogue-to-digital converter and micro-controller combination. These digital values are held by the micro-controller 12 and will be transmitted via the bus 3 upon command from the CPU 4.

The measurement module derives its power from the battery it is measuring and where the nominal battery voltage being monitored is too low for this purpose, the measuring module will include a step-up converter.

The micro-controller serial output port is isolated from the serial bus 3 by an optical isolation stage 15. Thus, in addition to sensing battery voltage and temperature and converting these values into digital form, the measurement module 2 provides isolation at the battery itself ensuring that the serial bus 3 is isolated with respect to ground. Further, micro-controller 12 in conjunction with CPU 4 provides data transfer from each measurement module by serial transmission. CPU 4 polls the micro-controller 12 in each measurement module to cause transfer of the stored voltage and temperature values to CPU4. A single set of values may be stored by micro-controller 12 or alternatively many sets of values may be stored in which case the polling frequency may be reduced.



Each measurement module 2 has an 8 bit address. To initially configure the measurement bus 2 the CPU 4 polls each address from 0 to 254, then compiles a table of valid addresses. This takes around 20 seconds. These addresses are then used for future communication. Replacing a measurement module simply requires the CPU 4 to re-scan all addresses on a measurement bus port. At 5760 baud this will take less than 6 seconds.

If the CPU 4 does not receive a response to a poll during normal operation, it will wait 10 seconds then run a complete address poll. The measurement module with the new address should inherit the configuration from the missing module.

Data is transferred most significant byte first. Asynchronous protocol follows RS232 format (but not voltage levels) at 5760 baud, 8 data bits, even parity and 1 stop bit. Voltages above 2.5V are treated as high and below 1V as low.

The measurement modules must use timing to synchronise to the measurement bus protocol as there is no delimiter support in the measurement bus protocol. After receiving the address byte, the measurement module looks for the start condition of the second byte. If this has not occurred within 4 bit times then the measurement module starts looking for another address byte.

The CPU 4 must send messages with inter-packet delays of greater than 8 bit times. The delay between transmitted bytes in the same packet should not exceed 3 bit times.

In a second embodiment each measurement module is connected to a small group of batteries 16, preferably four as shown in Figure 4. An analogue multiplexer 17 connects each battery 16, as instructed by the micro controller 12, to a signal conditioning module 18 which provides attenuation to a voltage suitable for an analogue-to-digital converter 19, and low pass filtering for noise reduction. An analogue temperature sensor 20 is attached to the case of each battery 16 to indicate exterior battery temperature. Both the output of each temperature sensor 20 and the output of the signal conditioning module 18 are connected to the inputs of the analogue-to-digital converter 19. The analogue-to-digital converter 19 used may be of the commercially available variety, and its output is connected to the input of the micro controller 12, which will store and transfer the data to the CPU 4. In this embodiment a fault in a

connection between adjacent batteries 21 can be detected by analysing the voltage drop between the terminals of those adjacent batteries.

In a third embodiment each measurement module is connected to a small group of batteries 16, preferably four as shown in Figure 5. A signal conditioning module 22 provides attenuation of all the voltages from the group of batteries 16 to a voltage suitable for an analogue-to-digital converter 19, and low pass filtering for noise reduction. An analogue temperature sensor 20 is attached to the case of each battery 16 to indicate exterior battery temperature. Both the output of each temperature sensor 20 and the outputs of the signal conditioning module 22 are connected to the inputs of the analogue-to-digital converter 19. A range of reference voltages 23 are required to compensate for the different voltage that each battery is referenced at. These reference voltages 23 are connected to another analogue multiplexer 24 which is connected to the input of the analogue-to-digital converter 19. The micro controller 12 will decide which of the reference voltages 23 to switch in based upon the overall voltage. The analogue-to-digital converter 19 used may be of the commercial available variety, and its output is connected to the input of the micro controller 12, which will store and transfer the data to the CPU 4. This embodiment has the advantage of speed over the second embodiment. However the second embodiment is more accurate, using the full resolution of the analogue to digital converter 19 over each battery, whereas for the third embodiment the analogue-to-digital converter 19 resolution spans over the overall voltage.

The present invention provides a battery monitoring system which has many advantages over conventional systems. Isolation provided near each battery ensures that no battery potential is connected to the central processing unit. Further, only one data cable pair is required for every ten (or in the case of the second and third embodiment up to forty) batteries and each measurement module can accommodate batteries from between 2 to 12 volts. For large battery banks the central processing units may be provided with additional serial ports to allow the monitoring of further multiples of ten (or forty) batteries. Because the measuring module is intended to be either located physically to the battery or integrated within the battery case, battery temperature may be measured without the need for separate outboard circuitry.

**CLAIMS**

1. A battery measuring module for a system for monitoring a plurality of batteries wherein said measuring module is associated with and measures parameters of one or more of a small number of physically proximate batteries, said measuring module  
5 comprising:
  - at least one analogue input port which in use is connected to at least one battery,
  - an analogue-to-digital converter connected to said at least one input port which produces digital values proportional to the voltage on said at least one input port,
  - a device which stores said digital values, and
  - 10 a digital output port,
  - said device presenting said digital values in serial form at the digital output port.
2. A battery measuring module as claimed in claim 1 wherein a voltage isolator stage is connected in cascade with said digital output port to ensure that the voltage potential at the output port does not exceed the digital signal voltage.
- 15 3. A battery measuring module as claimed in either claim 1 or claim 2 wherein said device is a microprocessor and said microprocessor together with switching devices comprises said analogue-to-digital converter.
4. A battery measuring module as claimed in any one of claims 1 to 3 wherein said measuring module is associated with a single battery.
- 20 5. A battery measuring module as claimed in claim 4 wherein said measurement module is fixed in close physical and thermal proximity to said single battery.
6. A battery measuring module as claimed in any of claims 1 to 5 wherein at least one temperature sensor is associated with a respective battery, said temperature sensor supplying a temperature dependent voltage to a said input port and said temperature  
25 dependent voltage is converted by said analogue-to-digital converter to a digital value which is also stored and serialised by said device.
7. A battery measuring module as claimed in any of claims 1 to 6 wherein said device has a digital input which input controls the serialisation of the stored digital values at said digital output.
- 30 8. A monitoring system for a bank of batteries comprising:
  - a digital central processing unit which is capable of storing and processing digital

parameters for each battery in the bank, said central processing unit having one or more serial input-output ports,

one or more data buses, each connected to a respective serial input-output port on said central processing unit,

5 and, connected to and in association with one or more of a small number of physically proximate batteries in said bank, a measuring module which may be polled by said central processing unit, said measuring module including:

at least one analogue input port which in use is connected to at least one battery,

an analogue-to-digital converter connected to said at least one input port which  
10 produces digital values proportional to the voltage on said at least one input port,

a device which stores said digital values,

and a digital input-output port,

said device presenting said digital values in serial form at the digital input-output port upon receipt of a polling signal at said port,

15 said digital input-output port of each measuring module being connected to said data bus or one of said data buses.

9. A monitoring system as claimed in claim 8 wherein a voltage isolator stage is connected in cascade with said digital output port to ensure that the voltage potential at the output port does not exceed the digital signal voltage.

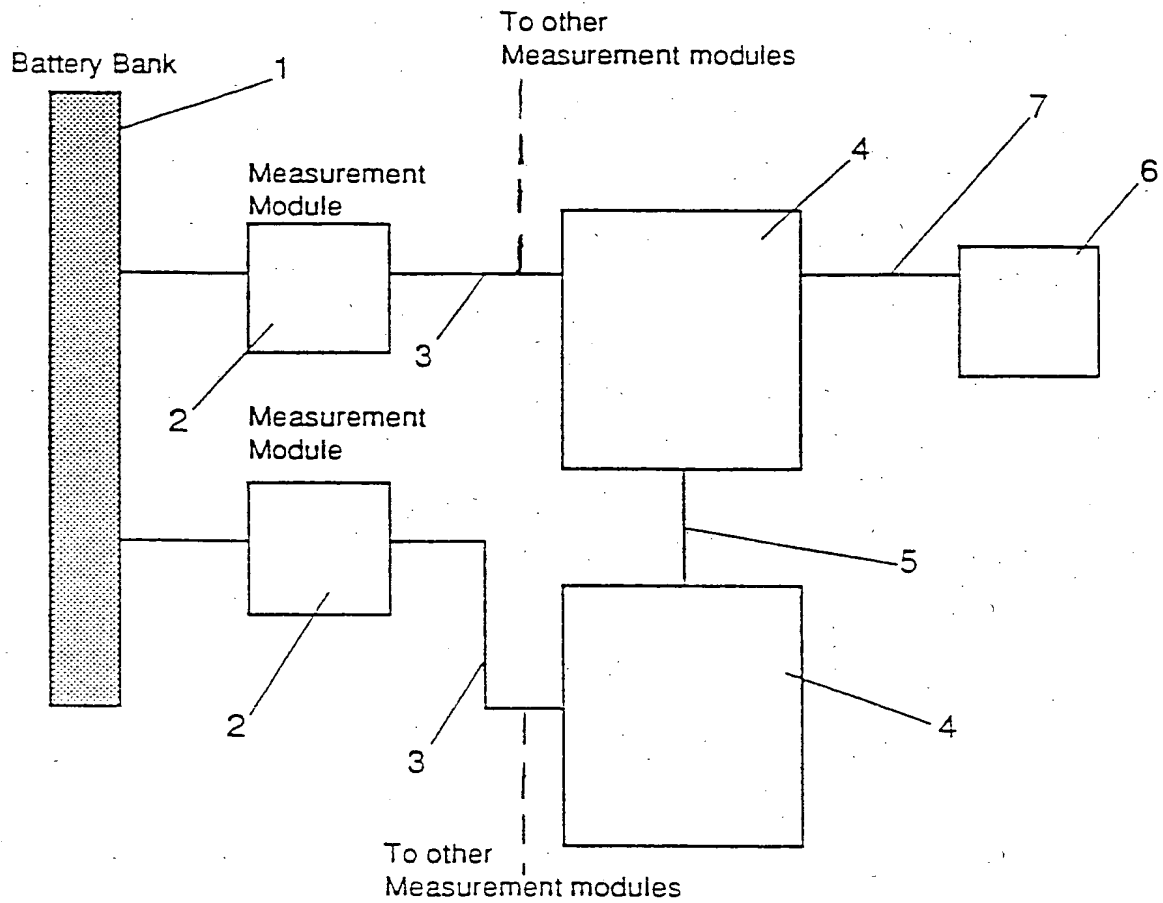
20 10. A monitoring system as claimed in either claim 8 or claim 9 wherein said device is a microprocessor and said microprocessor together with switching devices comprises said analogue-to-digital converter.

11. A monitoring system as claimed in any one of claims 8 to 10 wherein said measuring module is associated with a single battery.

25 12. A monitoring system as claimed in any of claims 7 to 9 wherein said measurement system is fixed in close physical and thermal proximity to said battery.

13. A monitoring system as claimed in any of claims 7 to 10 wherein a second input port and a temperature sensor are provided, said temperature sensor supplying a temperature dependent voltage to said second input port and said temperature dependent  
30 voltage is converted by said analogue-to-digital converter to a digital value which is also stored and serialised by said device.

14. A monitoring system as claimed in any of claims 7 to 11 wherein said device has a digital input which input controls the serialisation of the stored digital values at said digital output.

FIG. 1

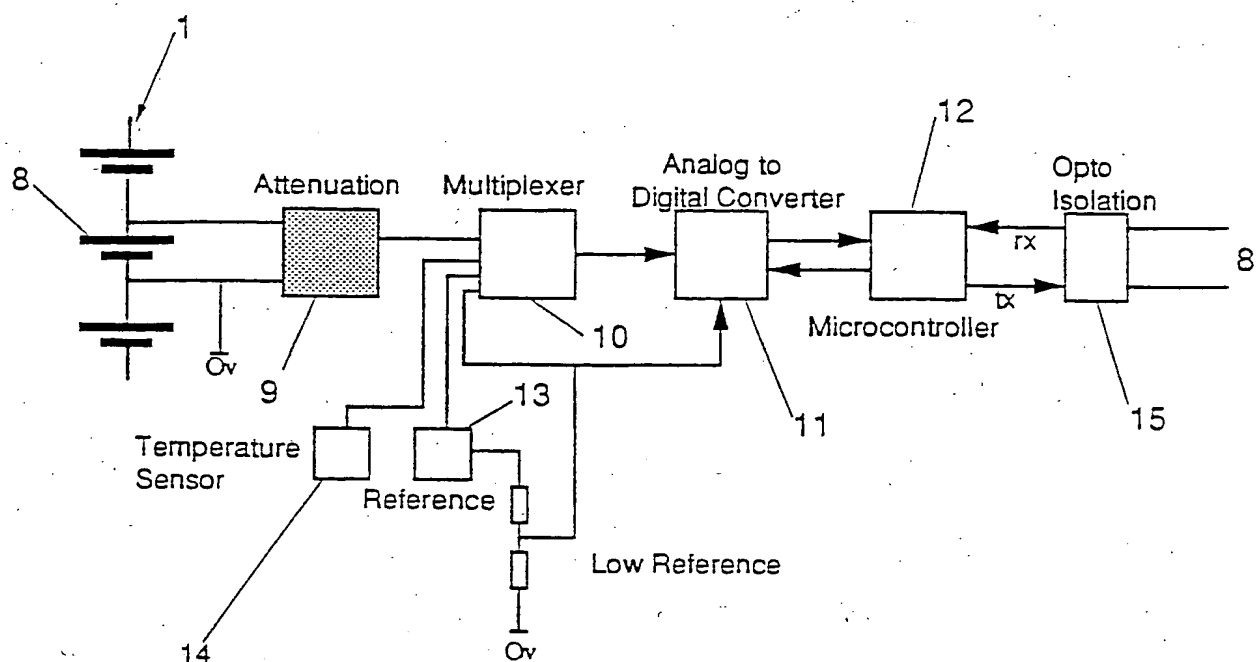


FIG. 2

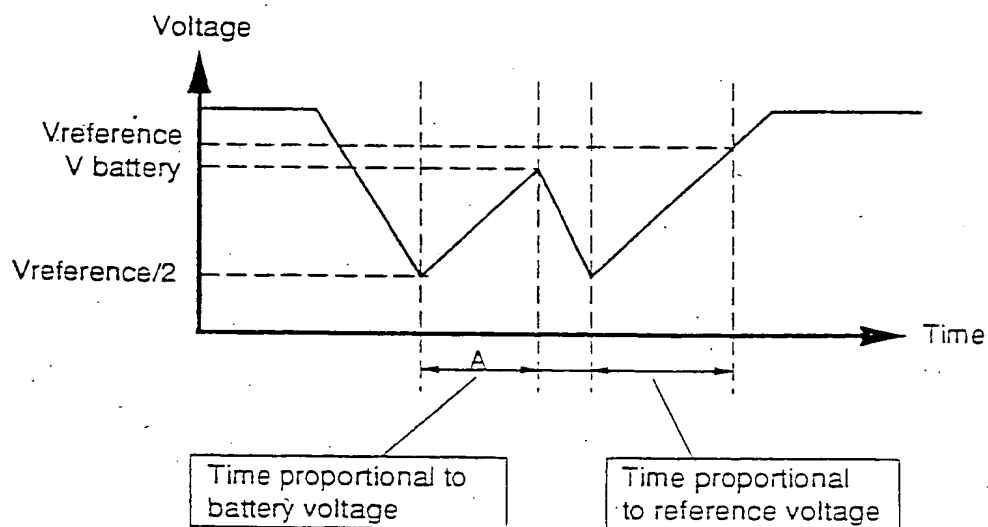
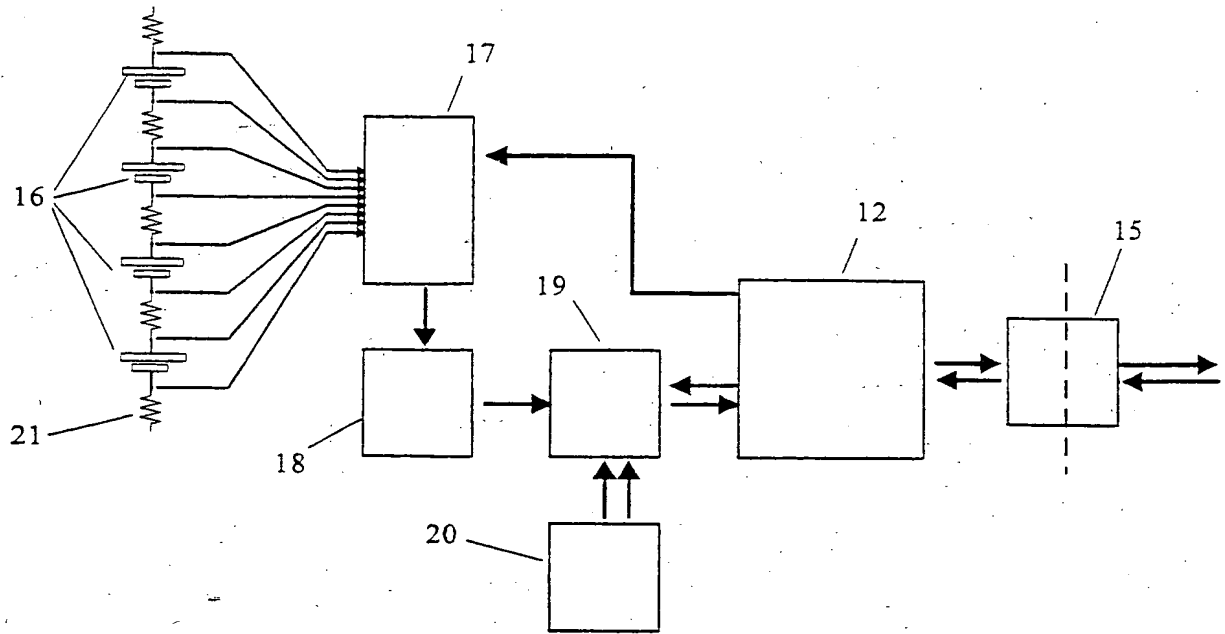
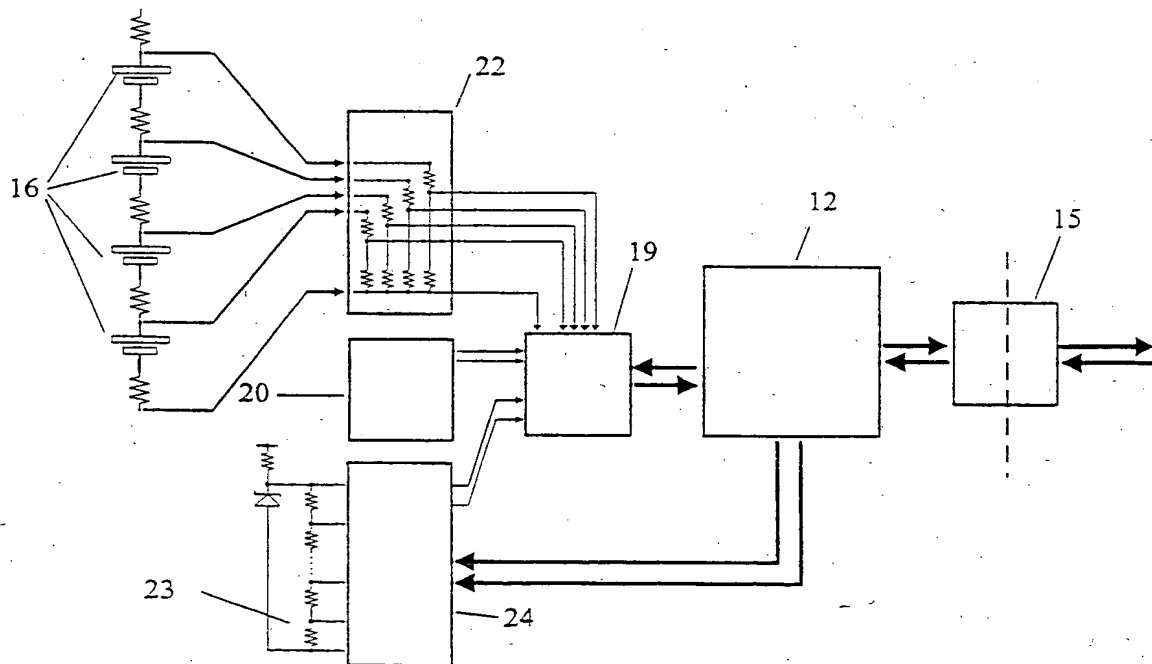


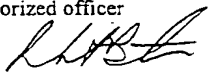
FIG. 3

**FIG. 4****FIG. 5**



# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/NZ 98/00168

<b>A. CLASSIFICATION OF SUBJECT MATTER</b>		
Int Cl <sup>6</sup> : H02H 7/18, 7/22 , 1/06; H02J 7/00		
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<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 5652502 A (van PHUOC et al) 29 July 1997 column 5 line 21 to column 6 line 45 and the claims	1,3-7,8,10-14 2,9
X A	US 4947123 A (MINEZAWA) 7 August 1990 see the entire document	1,3-8,10-14 2,9
A	FR 2748115 A (CIE EURO ACCUMULATEURS) 31 October 1997	1-14
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex		
<p>* Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&amp;" document member of the same patent family</p>		
Date of the actual completion of the international search 29 March 1999		Date of mailing of the international search report - 7 APR 1999
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (02) 6285 3929		Authorized officer  ROBERT BARTRAM Telephone No.: (02) 6283 2215

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/NZ 98/00168

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5666040 A (BOURBEAU) 9 September 1997	1-14
A	US 5656915 A (EAVES) 12 August 1997	1-14
A	US 5498950 A (OUWERKERK) 12 March 1996	1-14
A	US 4484140 A (DIEU) 20 November 1984	1-14

## INTERNATIONAL SEARCH REPORT

### Information on patent family members

International application No.  
PCT/NZ 98/00168

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member			
US	5652502	AU	41055/96	BR	9509140	CZ	9701398
		EP	793862	FI	971993	US	5633573
		WO	96/15563	ZA	9509575	US	5646508
		US	5691621	US	5710501	US	5789899
		US	5796239	IL	115955		
US	4947123	JP	1143984				
FR	2748115	NONE					
US	5666040	NONE					
US	5656915	NONE					
US	5498950	NONE					
US	4484140	NONE					
END OF ANNEX							

